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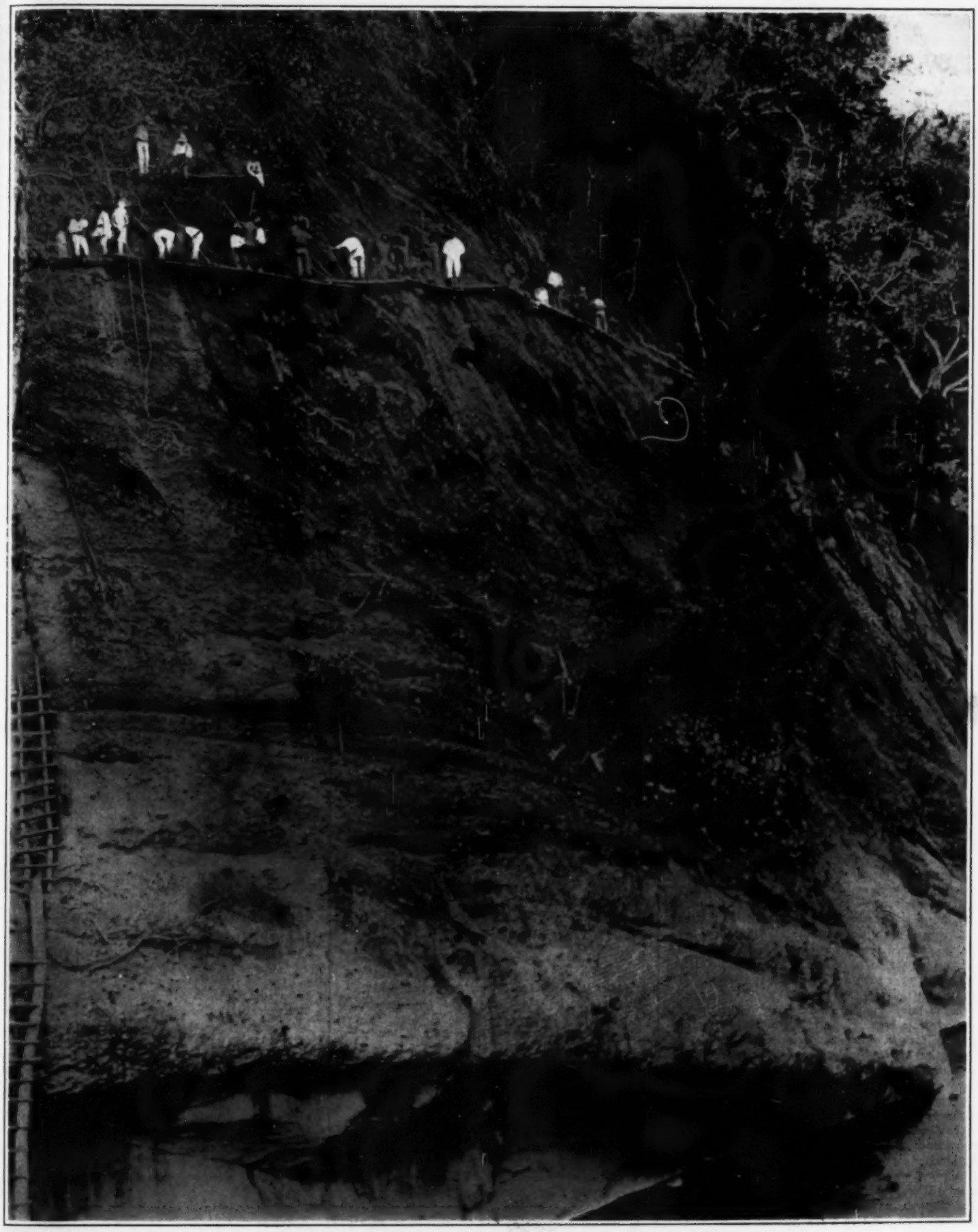


Benguet Road under construction—Working on the Hauris Cliff

TRANSPORTATION IN THE PHILIPPINES (See p. 336)

The Workman's Home—I*

Its Influence Upon Production in the Factory and Labor Turnover

By Leslie H. Allen

Recent investigations have shown that one of the most important causes of the present abnormal labor turnover is the lack of sufficient homes for the population around industrial plants. A questionnaire, prepared and circulated by the company with which the author is connected, elicited 840 replies, from which many interesting and valuable extracts are given. From a study of these replies, the general impression is gained that the causes of the labor turnover today are improper or insufficient housing, inadequate transportation, the general restlessness usual in war times, and a lack of care in placing men in positions for which they are best fitted.

One point that an investigation of housing conditions has brought out is that the type of house in which the workingman is generally lodged is not suited to his needs and is often beyond his earning power to support. Three- and four-room apartments and four- and five-room houses are an experimental type meeting with considerable success. A certain minimum requirement must be met, which should include a good-sized living room for general use, sleeping rooms of sufficient number and size to meet health demands, and adequate plumbing facilities. Let it be recognized at the outset that the problem is entirely distinct from that of the housing of the poor, a problem of equal urgency and of greater difficulty, a problem in which we all are, or ought to be, equally interested.

The high wages that now prevail are not bringing to the workingman either wealth or comfort. The shorter hours that the unions have devoted so much time and effort to secure have not produced any corresponding improvement in the workman's condition. This is largely because the workman is unable to secure a comfortable home in which to enjoy his hours of leisure. If he earns high wages rents are raised by landlords and prices of other commodities go up in like manner, and in growing centers of industry, houses are usually impossible to obtain. At the present time, when the cost of building is so high, new houses are not being built to accommodate the growth of population or its concentration in industrial centers engaged in munition work and shipbuilding, and the result is an altogether disgraceful amount of overcrowding. It is becoming the rule rather than the exception for two or even three shifts of men to occupy the same beds in overcrowded rooms, and it is practically impossible for any workman, skilled or unskilled, coming to a new town to bring his family with him; he has to come alone and crowd in as a lodger with others.

It is hardly necessary in this paper to present figures regarding labor turnover to a meeting of engineers; it is a pressing problem that you all know more about than the speaker. Ten years ago we should have felt rather ashamed of a turnover of 100 per cent per annum. Many large plants now consider themselves very fortunate if they can get below 300 per cent. Those who do not keep track of their figures may be inclined to dispute this. But those who through their employment department keep records of their labor turnover will all bear out this general statement.

The fact is, that in spite of high wages the living conditions in our manufacturing centers are so miserable that a workman cannot endure a long stay in one place, and he soon throws up his job and moves on to the next town for the sake of a change, in the vain hope that he will find something better than the conditions he has just left. Such men separated from their families, and roaming from place to place soon degenerate into the "floater" class that is such a big problem to our employment departments.

In order to bring out more clearly the importance of good and adequate housing as a means of reducing labor turnover, my company has just prepared and circulated a questionnaire among employers of labor, asking for figures on their labor turnover and on the character and sufficiency of the house accommodations around their plants. Prior to this, as far as could be ascertained, no data had been assembled on this relation, although the opinion has been widely held that housing has an important influence on labor turnover.

Eight hundred and forty replies were received, containing a mass of most interesting information. The replies were from typical plants in the eastern and middle-western states, some in cities and some in small towns, and may be taken as a fair average statement of conditions. As we expected, only a small proportion (18½ per cent) of our correspondents kept any record of their "hiring and firing"; of those who had kept records on turnover nearly a third had started this within a year. Very few of those answering stated that they housed all their help, but 17 per cent owned some houses.

In answer to our request for an expression of opinion as to the influence of good housing, nearly all replied that it was a benefit to a manufacturing plant, tended to hold the men and made them more contented and happier, but there was some division of opinion as to whether it reduced time lost through sickness.

The opinion is held by all manufacturers located in large cities, such as New York, Philadelphia and Buffalo, that in very large communities housing has no bearing upon labor supply—with the exception of one firm in Detroit, which attributes a large reduction in turnover to selecting its new employees from those who live within half a mile of the plant. No firm in a very large city shows any interest in housing, although in many cases the turnover is just as large. Whether this opinion is a correct one due to there being an excess of supply over demand for houses or for labor or both, in our big cities, or whether the opinion is fallacious, we are unable to say.

A table compiled from the answers received indicates that over 50 per cent of plants reporting which have adequate housing around them have a turnover below 50 per cent, while only one-third of the plants where housing is insufficient report as low a turnover as this. Combining all plants reporting a turnover of less than 100 per cent, the figures are only slightly in favor those which have adequate housing; above this point the advantage rests with the well-housed plants.

The figures obtained cannot be called conclusive, as such a small proportion keep records; and we are convinced that most of the firms with very large turnover did not care to confess it. We hear from reliable sources of many plants with turnover of from 500 per cent to 1000 per cent per annum, but no such figures were given in any of the replies we received. Of far greater interest and value are the replies returned with the questionnaire, some of the more interesting of which are quoted more or less fully.

A Pennsylvania mill has some very positive evidence of the cash value of good housing. Their manager writes us:

"Our two blast furnaces are located about twenty miles apart, and between them is the blast furnace of a rival company. We consider our housing facilities superior to theirs, and to give you an idea of the effect of this would state that for years past they have had to pay more per day, of the same number of hours, for all of the men they employ around their plant. Of course the wages differ for different positions, but any position at their plant pays more money than a corresponding position at either of our two plants.

"Furthermore, the general living conditions around one of our own plants are somewhat better than the other, and in view of this we find we have to pay a differential in the labor scale although the plants are only twenty miles apart. Hardly a month goes by that we do not get some men to come to us from this rival furnace, stating that the reason for moving is, though they get less wages, the housing conditions are better around our plants."

Each manufacturer who writes from Indianapolis emphasizes the fact that home ownership is the rule there and is a benefit to the community. For instance:

"Indianapolis is a town where a great many workmen own their own homes. It is possible for a man to buy a piece of property by making a small cash payment and making the balance of his payments at about what he would pay for rent. We believe that this is a very good thing for the city, and for the industries and the men located therein. It has a tendency to stop the shifting and constant changing of men, and is of an economical value because it promotes saving ad altogether produces a better grade of workmen and citizens.

"It is our belief that there is not the great shifting among the workmen of Indianapolis that you will find in other manufacturing cities. At the present time we do not doubt but that the population is shifting more than under normal conditions, but we do not believe that this percentage of change is as large with us as it is in other communities."

A small Connecticut town of home owners seems well content, as one reply says, "A great many of our employees own their own homes, a factor which tends to hold the men, makes them more contented and happier and is evidence of an earning power greater than in many lines of industries, and the result is that we do not have to give any particular thought to housing conditions."

From a thriving New York City a leading worsted mill writes us:

"We have only three or four houses and do not believe in building houses for laborers. We have a class of labor

*Presented before the American Society of Mechanical Engineers, at Worcester, Mass.

IMPORTANT ANNOUNCEMENT

Beginning with the first of January, 1920, the SCIENTIFIC AMERICAN SUPPLEMENT will be changed in form and in period of issue. The new journal, which will be published on the first of each month, will be known as the SCIENTIFIC AMERICAN MONTHLY. It will be composed of ninety-six pages of reading matter as against sixteen of the present weekly edition and the new page size will be nine by twelve inches.

The object of the SCIENTIFIC AMERICAN MONTHLY will be to keep our readers abreast of the progress of applied science by publishing, each month, summaries of the more important articles appearing in the current technical press. In each case the source of the article will be given so that the reader may study the complete original text if he so desires. This feature of the journal will be inavailable to a wide circle of readers, and particularly to progressive manufacturers who realize that they cannot afford to confine their reading to their own particular fields of technology, but must keep up with the march of science in contiguous and even apparently remote fields.

A most useful Department of the SCIENTIFIC AMERICAN MONTHLY will be that devoted to the work of the National Research Council. A section of the SCIENTIFIC AMERICAN MONTHLY will be used as an official organ of that body to keep the public informed of the work the Council is doing in organizing scientific research and introducing it into our industries. The aim of the Council is to make science as important an adjunct of manufacture in this country as it is in Germany.

To further this laudable work we have also arranged with the United Bureau of Standards to edit a Department in which the splendid research work of this branch of our Government service will be summarized and specially prepared for readers of the SCIENTIFIC AMERICAN MONTHLY. The National Academy of Sciences will also edit a Department devoted to the progress of American men of science. Similar arrangements are being made with the national technical societies so as to keep our readers in touch with the advance of science in various branches of technology.

We shall continue our policy of publishing the more important announcements of distinguished technologists, appearing in foreign as well as domestic publications, thereby reflecting the most advanced thought in science and technology throughout the world. In our columns will be found the complete text of significant European articles, furnishing often the only English translation of these papers that is obtainable.

The SCIENTIFIC AMERICAN MONTHLY, although a separate journal, will be closely allied to the regular weekly SCIENTIFIC AMERICAN and will supplement the work in that journal. Many important topics which, owing to the limitations of space, can be referred to only briefly in the latter, will be published in full in the SCIENTIFIC AMERICAN MONTHLY, thus making the new journal a most important if not absolutely indispensable adjunct to the SCIENTIFIC AMERICAN. For this reason the advantages of subscribing to both periodicals will be clearly apparent.

a little above the average, who build their own homes. Jamestown is noted for its laboring people owning beautiful homes. When an employee owns his own home and is interested in the city where he lives he will stand by the company that employs him much longer than he will if he lives in a tenement house belonging to the company."

The experience of the general manager of one of our largest colleries confirms the views expressed. He says:

"From close observation and study of results experienced at fourteen operating colleries, I can state specifically that where housing conditions excel there the better class of labor exists, as is demonstrated by higher efficiency in their work, cleaner play during their play time, and better homes for the wife and family.

"At such of these colleries operated by this company and where conveniences of a modern character have been placed at the disposal of workmen and their families, our labor is of the most efficient and also of the most stable character. We have found under these good conditions that even though the man did not fully appreciate the conveniences provided, in a great many instances after he and his family had moved away the wife has written to our superintendents asking if her husband can be placed at work again, and if a house can be obtained. At others of our colleries, especially those acquired by purchase after housing plans had been fully developed under the previous owners, we have observed that where inadequate thought and consideration had been given to house plans and conveniences difficulty was experienced in retaining the desired class of labor, even though the working conditions at the mine were equal to the working conditions at our colleries built throughout by ourselves."

Another colliery has had some interesting experiences to relate in keeping men by means of improving their houses.

"Our company is engaged in mining bituminous coal, and has over one thousand houses. Owing to the depressed condition of the trade for many years we were unable to keep our houses in proper and attractive condition, and had it not been for that condition prevailing generally, we would unquestionably have lost labor that otherwise we retained. During 1916 and 1917 we put all our houses in very much better condition and improved the surroundings. We have not any doubt that we have retained labor which would have gone to other places had we not done so, and our judgment is that it is wise to provide comfortable houses and attractive surroundings for the employees of any industrial establishment and that such a policy returns indirectly satisfactory financial results in the operation as a whole."

It is only fair to record adverse opinions. From a large textile concern in Montreal we learn that company housing is a disadvantage to them, "It makes them independent; if the company had not built they would have built their own homes and become fixtures." Another superintendent says:

"The question of companies building houses and renting them to their employees is one which very few people seem to agree on. Personally I think that any company makes a mistake in doing this. The working people as a whole suspect some ulterior reason for the company's apparent beneficence. To the average American, who usually has very fixed ideas about these matters, it is more or less repugnant."

Another of our correspondents emphasizes the importance of employees living within walking distance of the plant. A Buffalo manufacturer's evidence on this point is interesting: "We find that our most contented and steady, and probably best paid employees are those who live within walking distance of our plant. Our main difficulty at this time in getting and holding employees is that the transportation problem would be largely solved by better housing conditions in the vicinity of our plant."

Mr. R. S. Childs writes regarding the financial value of good housing:

"At Marcus Hook, Pa., is a company making artificial silks, with a pretty housing development which takes care of about one-half of the employees. They have a labor turnover of 15 per cent per month at the present time. Next door to them is a company making floor coverings, with no housing, and a turnover of 30 per cent per month. The silk company employs a larger proportion of skilled labor than the oilcloth company. Living conditions in that region are very bad and labor is very restless, due partly of course to the great shipyard developments. The oilcloth company recognizes the need of housing as the only solution of their manufacturing problem and figure they would save $200,000 a year thereby, inasmuch as they have unskilled labor handling fragile goods where a careless sweep of the arm will ruin $20 worth of goods."

The president of a large paper company near Philadelphia testifies to the steadiness of home-owning workmen:

"Our industry is the principal one in the town and most of our employees have been with us for a great many years. There seem to be enough houses in the neighborhood to provide room for all. The company owns some land which it sells to those employees who want to buy and build their own houses. We sell the land at a low price and on any terms which the purchaser may desire. We encourage our employees to buy their own homes, as our experience is that those who do so are much more dependable than those who do not. Our relations with our men have always been most pleasant and all of them take a personal interest in the property and success of the business."

A well-known crane manufacturer believes in selling houses to his men even at a loss:

"From the fact that nearly all of the company capital is needed in its business it is a very difficult matter for them to divert much of it to the construction of new houses, much as they would like to do so. We find that the employees were very anxious to buy these houses, but of course, the burden of the expense will have to be carried by the company for approximately ten years. We consider it desirable to have as many of our employees own their own homes as possible, because it makes them more thrifty and their families are better satisfied ordinarily, because of the added interest.

"The pressure of the housing situation is very apt to make it necessary for us to utilize women in the shop to some extent. The fact that they are already housed makes it easier to use them than to get help from outside sources and then have the housing problem get more serious than it is at present.

"While we have no definite statistics relative to the time lost by men who are properly housed and those who are not, we are of the opinion that a man working to pay for his own home will not lose any more time than is necessary and therefore will be on the job as steadily as it is possible for him to be. The satisfaction of owning one's own home and improving it is real. So far as we can recall we have only had one man who has bought his home leave the employ of the company in the past three years.

"The houses which the company built during the past year were sold to the workmen for considerably less than the actual cost of them; however, the difference between the actual cost and the selling price of the houses will not be lost in the long run, because we feel that the men will be better workmen and will stay longer with the company because of the situation."

Many can sympathize with this frank admission. "We were of the opinion that it would be beneficial to house our employees located in good houses in the village, and bought a large tract of land with that end in view, but gave it up for a bad job and have not done any building of that nature for some time, and would be glad to sell all we own or to hear they were burned up." This correspondent did not enlighten us further. In face of the successful work done by other concerns we suspect that some initial error was made in the organizing of the project. Such a letter only emphasizes the need for careful organization and management in housing development.

Mr. D. H. Andrews, president of a Boston bridge works, lays stress on the laudable desire of the workman to make his own home arrangements:

"For the great mass of people human welfare seems to consist largely in comfortable, healthful homes with income enough to provide food, clothing and some provision for the future, with a reasonable amount of recreation. The undisturbed possession of comfortable, healthful homes is such a prime factor in the contentment of employees that every far-seeing employer should and would, if circumstances will permit, have a deep and personal interest in this phase of the welfare of employees. Our experience with employees is that generally if the location of their employment will admit of it, they prefer to settle the question of their homes independent of any consideration which may, to them, savor of paternalism on the part of their employers. If the employment is of stable permanence and the employer can provide homes for employees with an arrangement for the gradual rental purchase of same by the employee, that would seem to relieve the laudable sensitiveness of the employee and to promise the best solution of the housing problem." This can be done in a big metropolis. It is not so easy in the smaller towns.

Another believer in company housing anxious to "control" his men writes from Pittsburgh:

"We have a great number of plants. We don't attempt to house all our men at the plants, because they are all located near small towns, and a certain number of them are drawn from these towns, but we house as many men as we can near the works and are building houses just as fast as we can get employees to rent them. We find it is best to have employees live near the works, and if you have them in your own houses, you can control them better. During the shortage of labor which we are all now experiencing, if we did not have houses near our plants, in many instances we would have been shorter of labor than we now are. At one of our factories where we employ between two hundred and three hundred laborers, we house the majority of them. We have built practically the whole town. As a general proposition, the writer has handled large lots of men direct for the last thirty years, and would, if possible, house every man on company property."

The attitude of this writer is that of what we may term "the old school" and is quite a contrast to the views generally held today as voiced by Mr. Andrews.

A contented Maine textile concern says "we have been building a few houses every year or two and almost never lose a well-housed family." An Ontario manager writes: "Unfortunately we haven't any residences in which to house our men, and the fact that we haven't operates against us because the town is crowded, and the first thing an out-of-town mechanic asks in answering our advertisement is about housing facilities." This experience is borne out by a Connecticut metal worker who is building houses, "Not to house my present force—they are already located, but to add to my force by bringing in out-of-town men. They will not come unless I can find a home for them."

A Buffalo textile firm says: "We have a splendid organization, and while there is considerable changing amongst our employees, particularly the girls, we think it is due to the existing unrest among the laboring class. Most of our employees live in the immediate neighborhood, and about 60 per cent of our entire staff has been with us ever since we located here in 1913. The living conditions in the immediate vicinity of our mill are splendid, and we believe that this is one of the main reasons why we haven't experienced a labor shortage to any extent. We, of course, realize that our possibilities of getting new and additional help are not as good today as they were when we located here; on the other hand, we have never been handicapped to any extent on account of being unable to secure employees. In our estimation, good housing facilities have a tendency toward holding men that are married particularly; and the loss in time through sickness that our men have sustained is so small that it is not to be taken into consideration."

Mr. W. H. Ham, manager of a Bridgeport company, comments on the prevailing "restlessness" and has some important and interesting suggestions to make.

"Labor is restless at the present time. The single man is bound to be a rover. The young married man is somewhat better, but still has a tendency to rove and to seek better conditions and better wages because of lack of ties. The unmarried man should be free from any restraints which would handicap his ability to advance himself. My feeling is that the best way to prevent roving of the harmful type is to build up the associations in manufacturing towns to such an extent that the unmarried man may have membership in proper kinds of associations, which will teach him to advance rather than stay still. Sports for both winter and summer are very important items. Winter sports are very lacking in most of the manufacturing cities. The competition in physical exercise is very keenly appreciated by the average working man.

"I believe in the school for advancement of knowledge in the trade and the wholesome surroundings of a sufficient number of playgrounds so that we can have athletics for a very much larger number. This will have a great deal to do with the turnover of the unmarried man in the factory. I believe the turnover among the married men with small families can be prevented by building *attractive small* homes."

This view is endorsed by an industrial superintendent in Providence. Like all large manufacturers in big cities he disregards the housing problem. He says:

"The increased turnover in 1917 is due to military service and war conditions and has no relation to the housing question. The main part of our experienced force has been stable to as great a degree as could be expected, the greatest turnover being among new and inexperienced help 'hired out' to increase our force."

In the big centers the employer does not consider housing such an important element. From Orange, N. J., Mr. Clark writes:

"The Edison interests do not attribute any of their labor turnover to lack of proper housing. We are so situated that we draw our employees from a very thickly populated district, which does not make it necessary for us to house any of our employees.

"Particular emphasis is made to the lack of proper housing at this time. This is due to the war-work factories and shipbuilding plants that grow up over night. In these cases it is not a question of housing, it is purely a question of who pays the highest wages. The large labor turnover at this time is due entirely to what I might term competitive bidding for men's services, and housing conditions are unquestionably a secondary consideration."

(*To be continued*)

The car containing the adzing machine and the power plant

A Complete Wood Preserving Plant Mounted on Cars*

Portable Equipment Which May be Readily Moved to Sources of Timber Supply

The Pennsylvania Railroad has been using a tie treating plant for the past eighteen months that is mounted entirely on cars. This includes not only the retorts but the adzing and boring equipment as well, so that the complete outfit, ready for immediate use, may be transported to the points of principal tie supply and thus save the possible back haul occurring where ties must be transported from the wood lots to the treating plant and then to the point of use in the track. Such a plant is particularly adaptable to districts wherein a large proportion of the ties used are purchased locally and stored along the right of way to season. However, the distribution of ties has been so dislocated in recent months that the plant on the Pennsylvania has operated continuously in the Mt. Union (Pa.) tie yard, where, in 1918, 276,156 ties were treated, adzed, and bored at a cost, exclusive of royalties, rentals, etc., of $0.1211 per tie.

Essentially the plant consists of a car housing the power plant and adzing and boring machines, two cars carrying tracks on which the retort cars travel and a car for the treating cylinders. All of these cars are built specially for their particular purposes and are arranged in the train in the order named. The train may be moved from one locality to another as any other train, clearances having been maintained in the design of cars, or it may be moved locally under its own power, the adzing and boring car being equipped with the proper gearing for this purpose.

The adzing car, in addition to containing the adzing and boring machines and conveyors located in one end of the car, furnishes space for a 60-hp. gas engine, a stationary boiler of 50 hp. for generating steam for the operation of the pumps on the treating car, fuel storage for the boiler, tanks for gasolene and kerosene, a bench gainor knife setter, bench grinder turned by a small gas engine, and a work bench for general purposes. The boiler is located in the far end of the adzing car to keep the fire as far as possible from the creosote. The shavings and borings are conveyed away from the machines and are used with coal for fuel under the boiler.

The track cars, two in number, are 50 feet long with two tracks for the tram cars on their deck, and two additional tracks raised on steel frame work to the elevation of the upper cylinder on the treating car. A ball bearing gravity roller conveyor extends alongside the adzing car leading from the machine to the first track car, which is supplied with turntables at the end adjoining the adzing car. Switches at the end of the second car adjoining the treating car permit flexible operation of the tram cars, it being possible to discharge from either cylnder to either side of the track car as occasion demands.

One of the photographs shows the arrangement of the treating cylinders on the treating car. As may be seen, two are placed on the deck of the car with the third superimposed. The treating car equipment consists of two pumps and the necessary gages and valves, one a low pressure pump working to about 200 pounds and used for pumping creosote into the cylinders, and the other a high pressure pump (600 pound) used for treating purposes. Steam coils carried on the inside of the cylinders through which all exhaust steam passes serve to heat the creosote.

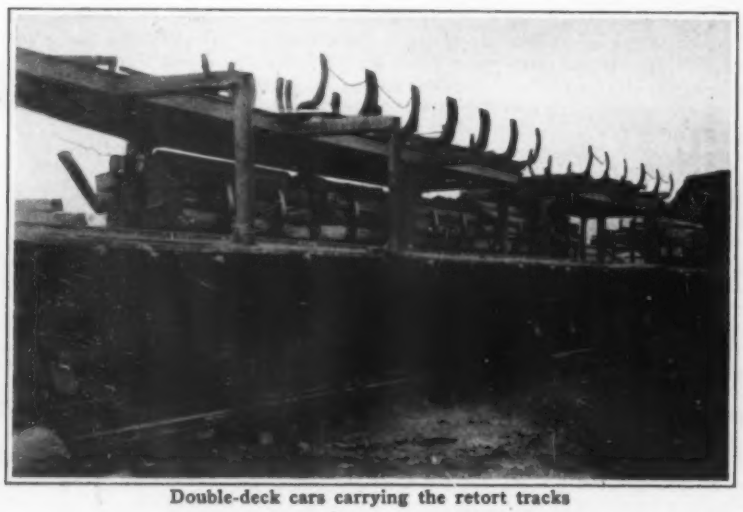
Each cylinder is supplied with oil sprinkling or spraying apparatus consisting of a main pipe, two inches in diameter, running the full length of cylinders with smaller pipes leading into the cylinders to spray the creosote over the ties. The creosote for the plant is furnished in tank cars, which are spotted beyond the cylinder car, and which, with little trouble, can be connected up with the pumping apparatus on the treating car.

The cylinders are four feet in diameter and sixty-three feet long, or sufficient to admit seven tram cars with their loads, which average 100 ties. Running to capacity, the outfit is capable of treating 100 ties per hour.

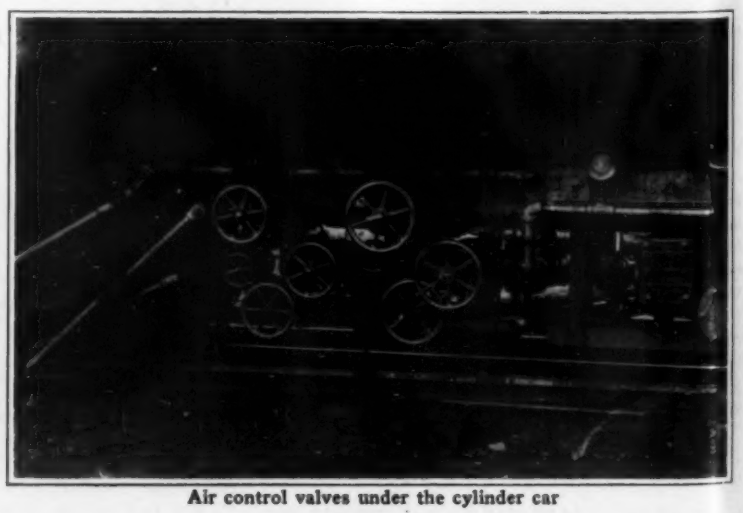
Under normal conditions the force employed consists of two men on the treating car, one to run the pumps and one to open and shut the doors of the cylinders, three men on the adzing and boring car, including an engineman, a fireman and an operator at the adzing and boring machine, and eight laborers. The engineer is in charge of operations, including general repairs, and supervises the labor forces.

In operation the ties are conveyed from the ground or piles to the adzing machine, where they are shaped for tie plates, after which they pass on to the boring machine and then out to the gravity roll conveyor leading to the tram cars ready for introduction into the cylinders for treatment. When in use along the right of way

*From the *Railway Age*.



Double-deck cars carrying the retort tracks



Air control valves under the cylinder car

the operation is so planned that car containing untreated ties is spotted at the adzing car and the ties are unloaded upon the conveyor. The empty car may then be shifted slightly ahead to the proper position for receiving the ties as they are discharged from the cylinder. As noted above, however, the track arrangement on the cars permits the varying of this cycle to meet different conditions.

In operating the plant it is not necessary to utilize all three cylinders. For convenience in describing the operation it will, however, be assumed that all three are to be used and reference will be made to the cylinders by the letters *A*, *B* and *C*. To start, a charge of ties is placed in any cylinder, which will be called *B*. Cylinder *C* is then filled with creosote by means of the pump, letting the air escape into *A*. The air from *A* is then let into *B*, while at the same time the charge of ties is being sprinkled with oil from the spraying apparatus, thus subjecting the ties to pressure and oil simultaneously. After the sprinkling, all of the air in *A* is pumped into *B*, treating the charge in *B* by pumping oil from the source of supply, raising the pressure in *B* to 450 pounds, holding it approximately 30 min. During this operation cylinder *C* becomes ready to receive a charge of ties which is placed. Then in treating *B* air is forced into the charge in *C*, drawing a vacuum in *A*. That is to say, when running high pressure on a charge that has had air and oil a vacuum is drawn on a treated charge while running oil on the last charge in. The cars are hauled in and out of the cylinders by a line operated by the gas engine.

Results of the Total Solar Eclipse of May 29 and the Relativity Theory

By A. C. D. Crommelin

The results obtained at the total solar eclipse of May 29 last were reported at a joint meeting of the Royal and the Royal Astronomical Societies, held on November 6. The stations occupied were Sobral, in North Brazil, and Principe Island. Two cameras were employed at Sobral, the 13-inch objective of the Greenwich astrographic equatorial, and a 4-inch lens, of 19-foot focus, lent, together with an 8-inch coelostat by the Royal Irish Academy. It was realized before the expedition started, that the coelostat was scarcely suitable for observations of such extreme precision as were required to detect and measure the small shift in the place of the stars that might be produced by the sun's attraction. War conditions, however, made it impossible to construct a suitable equatorial mounting, though it is hoped that this may be done before the eclipse of 1922.

The results, to some extent, but, fortunately, not entirely, justified these apprehensions. The eclipse plates taken with the 13-in. (stooped down to 8 in.) are out of focus. Since the focus was good on photographs taken at night a few hours earlier, and also on the check plates taken before sunrise in July, the explanation appears to be a change of figure of the coelostat mirror, due to the heat of the sun. These plates were compared with the July check plates by using a duplex micrometer. They show an undoubted graviational shift, the amount at the sun's limb being 0.93″ or 0.99″, according to two different methods of treatment. The probable error, as estimated by the individual discordances, is about 0.3″, but there is reason to suspect systematic error, owing to the very different character of the star-images on the eclipse and check plates. This instrument supports the Newtonian shift, the amount of which is 0.87″ at the limb. There is one mode of treatment by which the result comes out in better accord with those of the other instruments. Making the assumption that the bad focus did not alter the scale, and deducting this from the July plates, the value of the shift becomes 1.52″.

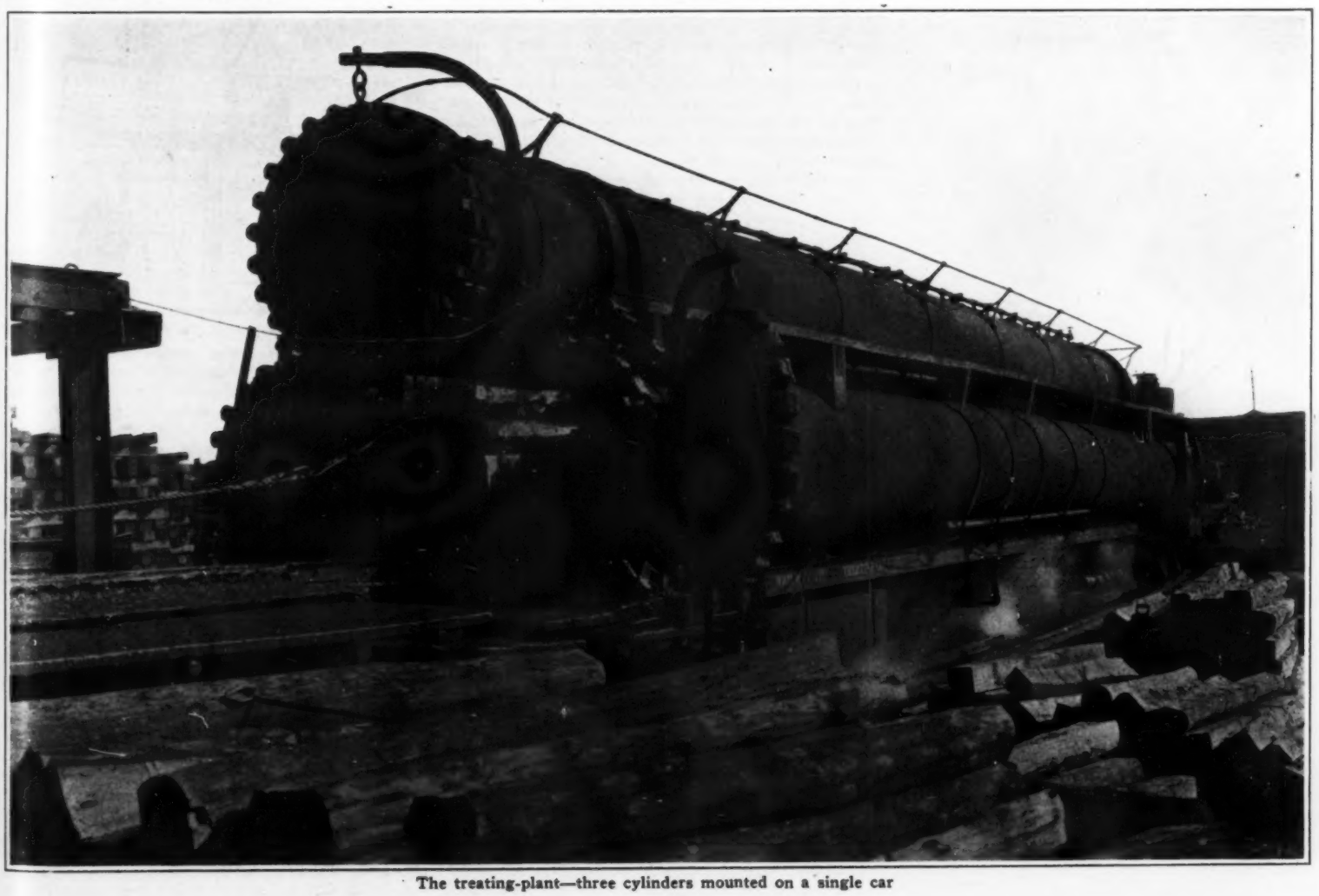
The results with the 4-in. lens are much more satisfactory. The star-images are well defined, and their character is the same on the eclipse and check plates. As the duplex micrometer would not fit these plates, a key-plate, on which the film was placed away from the lens, was taken in July, and all the plates in turn were placed in contact with this plate and compared with it. The resulting shift at the limb is 1.98″, with a probable error of 0.12″. The values from the separate stars are in good accord, and they support the fact of the shift varying inversely as the distance from the sun's centre; they are thus unfavorable to its being due to refraction, as was suggested by Prof. Newall at the meeting. Moreover, Prof. Lindemann pointed out that the comets of 1880 and 1882 had traversed this region without giving the slightest evidence of having encountered resistance; as their speed was about 300 miles per second, a vivid idea is given of the etreme tenuity of any medium that they encountered.

The Principe expedition was less fortunate in the matter of weather, but a few plates showed five stars. Since no check plates of the eclipse field could be taken there, another field near Arcturus was photographed, and both it and the eclipse plates were compared with plates of the same fields taken at Oxford with the same object-glass. It was, moreover, necessary to assume that the scale of the eclipse plates was the same as that of the check plate. This is justified by the fact that the diurnal variation of temperature in Principe is only some 4°F., and that there had been no bright sunshine on the mirror before totality. The measures indicate a shift at the limb of 1.60″, with a probable error of 0.3″.

It will be seen that the mean of this result and that with the 4-in. at Sobral agrees very closely with Einstein's predicted value 1.75″. It was generally acknowledged at the meeting that this agreement, combined with the explanation of the motion of the perihelion of Mercury, went far to establish his theory as an objective reality. Sir J. J. Thomson, who presided, spoke of the verification as epoch-making; he suggested that it would probably have a bearing on electrical theory, but he regretted the very complicated form in which Einstein expressed his theory, and hoped that it might be possible to put it into a form in which it would be more generally comprehensible and useful.

Dr. Silberstein laid great stress on the failure to confirm Einstein's third prediction, that of the displacement of lines in the sun's spectrum towards the red, to the amount of 1/20 Angström unit; this had not been verified, in spite of the careful search made by Dr. St. John and Mr. Evershed. As the probable error of their measures was much less than the quantity predicted, he looked on this result as final; some people had suggested that the shift might be verified by a systematic outward movement of the photosphere, but as Dr. St. John made measures both at the sun's centre and limbs, that suggestion was not tenable. Prof. Eddington admitted that the failure threw doubt on the validity of some of the steps which led Einstein to his gravitational result; but he contended that the two other successes indicated that the result was right, even if reached by a wrong method.

There was some discussion on Prof. Lindemann's method of photographing stars in daylight by the use of red screens. However, the eclipse method seems more trustworthy, and the Astronomer Royal expressed the hope that the eclipse of 1922 might be observed with equatorials. The star-field is not so rich as in the late eclipse, but with longer exposure much fainter stars could be recorded. The eclipse-track crosses the Maldive Islands and Australia, and is therefore fairly accessible.



The treating-plant—three cylinders mounted on a single car

Fuel Blending*

The Sandwich System

By E. W. L. Nicol

"It may be asked how it has happened that hitherto the smokeless combustion of fuel has not been effected. I answer, because the chemistry of combustion has been neglected, not in the laboratory, but in practice; and because the construction of our furnaces has been too much left to those who know little of the chemical properties of the materials which are to be consumed in them."

Written over seventy-three years ago by C. Wye Williams, the pioneer in the movement to obtain more efficient use of coal in steam boilers, these words are still largely applicable to the position as it is today. A survey of the Patent Office records over a period much less than seventy-three years adequately refutes, indeed, the charge of neglect; and thousands of patents have been granted for inventions relating directly or indirectly to improvements in boiler and furnace construction, which aim chiefly at the efficient or smokeless combustion of bituminous coal. But notwithstanding these and the

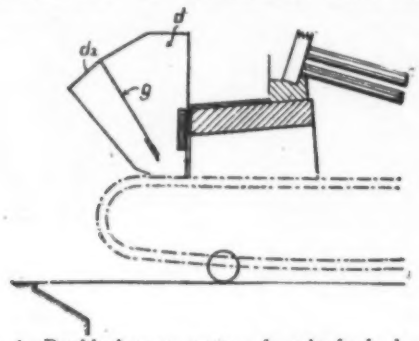


Fig. 1—Double hopper system d_2, coke-feed; d, coal; g, separating diaphragm.

sustained efforts of many engineers and men of science the average thermal efficiency of coal-fired steam boilers, of all types and sizes, has quite recently been estimated by competent authorities at about 50 per cent. Based so far as possible upon statements of fuel consumption and water evaporation, which have been submitted by steam users to the Coal Controller, the official opinion is that "50 per cent boiler efficiency would certainly not be too high a figure."

These figures not only show a deplorable state of inefficiency and waste on a colossal scale, but also tend to prove that the best possible adaptation of both furnace and steam boiler construction to suit the complex composition and characteristics of our native coal fuels is largely impracticable. Certainly, but for the efforts of engineers and inventors they would have been appreciably worse; but in any case, failure to apply to all kinds of boilers conditions which will with ordinary skill ensure smokeless and efficient combustion must be ad-

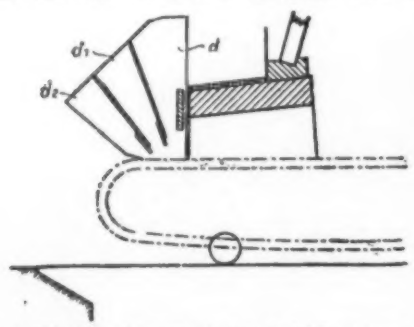


Fig. 2—Modification of the "sandwich" system, additional coal fed next the grate from a third hopper, d.

mitted. It must also be conceded that for economic reasons, modern stoking apparatus is largely inapplicable to the thousands of steam boilers now in use. Still less available is the skill necessary for the intelligent use of modern indicating, recording, and stoking apparatus.

REMEDIES, OLD AND NEW

Since the advent of the present coal crisis and the inception of State Control of coal mines, more than usual interest has been bestowed upon the working of steam boilers and coal conservation. Various remedies have been suggested with the view of obtaining better results; but, with one exception, expert investigation and scientific methods of control have so far been apparently the only lines upon which either private or official action has been taken. These measures are, of course, very desirable, and so far as they have been applied and maintained they have effected economies which will materially help the situation; but these expedients must, in the light of past experience, be regarded not as a panacea but merely as palliatives which require not less, but more, of the scientific knowledge and skill which are apparently not possessed by the average steam user. On the other hand, it is of the essence of good management not to complicate, but to eliminate or render "fool-proof," so far as possible, operations or processes which must be entrusted to unskilled operatives. The efficient combustion of bituminous coal under steam boilers is acknowledged to be a thermo-chemical process of great complexity; but recent experience has proved that even this operation is amenable to treatment by a process of complete or partial elimination.

On many important steam plants the use of bituminous coal, with all its attendant inefficiency and waste, has now been entirely eliminated by the substitution of coke, the furnaces being suitably adapted; but before the formation of the London Coke Committee, five years ago, the use of coke as fuel for steam raising was limited to relatively small hand-fired steam plants. The adaptation of certain types of existing mechanical stokers to the use of coke, or mixtures of coke and coal, has, however, proved to be a more difficult problem; but it may now be claimed that this has been satisfactorily accomplished. By means of a simple system of blending introduced by the present writer the use of bituminous coal as fuel for mechanical stoking is reduced to a minimum, while the relatively small proportion of coal so used is used to better advantage than has hitherto been found possible under ordinary every-day conditions. This "sandwich" system of blending and feeding fuel to steam boiler furnaces, which incidentally permits a material increase in national wealth through by-product recovery, enjoys the distinction of having been accorded official encouragement by the Coal Mines Department of the Board of Trade, Readily applicable to existing mechanical stokers, it has already been adopted by many important steam users, primarily as a temporary expedient, in order to maintain essential public services during the period of acute coal shortage; but extensive alterations to overhead storage bunkers which have since been carried out, with the object of facilitating fuel-blending operations, appear to indicate that many of the more important users have adopted the system as a permanent institution, not merely from patriotic considerations but simply because it pays.

Certain definite factors have hitherto limited the range of fuels which could be utilized economically for steam raising at electricity supply, tramway, and other power stations. The transport-economizing "zone" system of satisfying local demands from the nearest sources of fuel supply has in this country, as well as abroad, revealed many faults in power-station design which have unnecessarily limited the range of fuels available. Almost invariably these stations have been laid out on the assumption that free-burning bituminous coal of uniform grade and quality would be the staple fuel used. Draught, mechanical coal-handling, storing and stoking appliances are more or less inflexible, and no provision has been made for the systematic grading and blending of different kinds of fuel. In the light of present knowledge, and in view of the economies obtainable from the zone system of fuel distribution, such methods must be regarded as primitive; except, perhaps, for their crude simplicity, they have nothing to warrant their embodiment in new, or their continuance in existing, power stations.

ADVANTAGES OF BLENDING

So far as the writer is aware, no attempt has hitherto been made to blend solid fuels having different physical and chemical characteristics for the purpose of improving the efficiency and intensity of combustion. Mainly with the object of complying with specified conditions as to calorific power, viscosity, flash point, &c., fuel oils and spirits are frequently blended by distillers and dealers. The blending of coal gas with carburetted or blue water gas so that the resultant admixture conforms to the statutory standard of calorific power, &c., is also a practice which has been brought within the region of an exact science by gas engineers; and the possibility of blending in order to improve the efficiency of combustion of gaseous fuel is a subject which is now receiving close attention. Users of pulverized coal also recognize the advantages of blending high and low grade fuel for specific purposes or for commercial considerations, a practice to which this system of combustion readily lends itself. For use in rotary cement kilns, for instance, a certain minimum of volatile combustible in the pulverized fuel is necessary in order to avoid risk of unburnt carbon finding its way into the cement material. With this kowledge, the large user, who is usually also a shrewd buyer, takes advantage of variations in prices, selecting those fuels which for the time being are the most advantageous and, having ascertained their proximate analyses, he proceeds to compound a mixture of two or more different kinds that will conform to his requirements at minimum cost. This is one of the advantages of this system which has very considerable commercial importance, but apart from the larger consideration of coal conservation it may be of interest to examine to what extent the ordinary power user may avail himself of the practical and financial advantages that accrue from the judicious blending of different kinds or grades of coal—bitumious, lignitic, or anthracite, or peat—with gas coke, cannel coke, or coke breeze, with the object of improving the thermal and commercial efficiency of his boiler plant.

INHERENT DEFECTS OF COAL AS FUEL

Considered merely as fuel, the disadvantages of bituminous coal have been recognized from very early times,

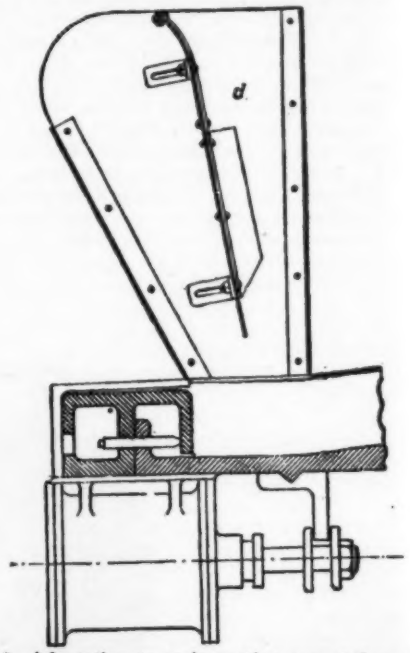


Fig. 3—Adaptation to reciprocating ram stokers with lateral movement of diaphragm.

and that particular characteristic which the late Professor Lewes aptly described as "the curse of coal," *i.e.*, its low volatilizing temperature, is probably the root cause of the low average efficiencies realized in its direct use as fuel. As is well known, many of the rich hydrocarbons contained in it begin to distil off at temperatures much below those necessary to effect their ignition and complete combustion, and are therefore largely wasted; but, incidentally, it is this very characteristic of coal which enables it, by the process of carbonization and by-product recovery, to contribute so largely towards the national wealth.

In addition to the human element, the expression "boiler efficiency" includes at least three important factors:—(1) The efficiency of the boiler itself, or its capacity for conveying heat to the water and steam inside; (2) "furnace efficiency," or its capacity for converting fuel into useful heat; and (3) "fuel efficiency," which may be described as its capacity for being converted from potential energy into useful heat energy. Beyond the maintenance of the plant in good condition, the first two factors are largely incapable of variation in most of the steam boilers now in use; but the third factor, "fuel efficiency," has been proved capable of considerable variation. Obviously, all fuels, whether solid, liquid, or gaseous, are not equally efficient; and by blending, either before or at the point of ignition, variable results are obtainable. To judge by the various systems of buying and selling coal, gas and other fuel merely on the basis

*From *Times Engineering Supplement*, (*London*).

of its calorific power, as distinguished from its calorific intensity, the importance of the bearing of this factor upon the fuel cost of steam production and heating does not appear to have been fully appreciated.

So long ago as 1901 Mr. W. H. Booth advanced what was then a new theory of two-stage bituminous combustion in boiler furnaces. He showed that the furnace temperatures attainable in ordinary circumstances depend not so much upon the relative calorific power of coal as upon its composition. In a piece of coal, he argued, there exist solid carbon, solid hydrogen, and solid oxygen. It is well known how great is the amount of heat required to be taken from the so-called permanent gases in order to reduce them to liquid form, and how it is still more difficult to render them solid; and the solid coal will dissolve into combustible vapor only at the expense of the heat in surrounding bodies, as ice dissolves to water, or water to vapor, at the expense of heat. In gas making, it obtains it from the fuel used in the retort or producer furnace, and his process of carbonization and gasification absorbs anything from 15 to 25 per cent of the heat available in the coal. In the steam boiler furnace it obtains it from the incandescent fuel in the grate. If the volatile parts of ordinary bituminous coal could be caused to escape entirely unburnt, Mr. Booth further showed, the net fuel efficiency might be as low as 25 per cent, as the volatile hydrocarbons carry with them not merely their own calorific capacity but also the latent heat absorbed by them in the process of distillation. In ordinary circumstances the volatile matter in a ton of coal in the process of combustion evolves 12,000 cubic feet or more of rich combustible gas; and no doubt the escape of large volumes of this gas unburnt, or only partially burnt, together with its latent heat, accounts largely for the waste which appears to be unavoidable in the use of bituminous coal as fuel.

In dealing with non-bituminous fuel such as coke, which is a "single stage" fuel, experience has proved that efficient combustion and high calorific effect are much easier to secure than in the case of bituminous coal; and the theory advanced by Mr. Booth affords an explanation. Coal, coke, and gas are related to each other much as are ice, water and steam. Judged by its analysis, coke should not have a calorific effect superior to that of coal, such as it possesses; but the explanation probably is that, the process of combustion being already far advanced by the heat-absorbing process of carbonization, less heat is required to gasify it than is necessary in the case of coal. There is also a marked difference in the specific heats of coal and coke, and the latter, of course, burns without the formation of water.

ACTUAL WORKING RESULTS

Some of the actual working results obtained at important power stations, with mechanical stokers of the chain-grate type using unscreened crushed coke or breeze as a diluent in proportions varying from about 30 to about 75 per cent, are now available. Those supplied by the London Hydraulic Power Company were obtained in the ordinary course of working at one of their hydraulic pumping stations where the "sandwich" system of blending has been in use for some time. According to the report of their chief engineer, the tests were made for the se of ascertaining the comparative efficiency when burning (1) coal, slack, and unscreened broken coke; and (2) coal only, under exactly similar conditions of natural draught, &c., on the same (B. and W.) boiler and economizer. The normal guaranteed capacity of the boiler was 6,000 pounds per hour.

The usual methods of measuring the feed water by volume were employed, and observations of feed water and flue gas temperature were taken at fifteen-minute intervals. In Test No. 1 the coal and coke were each weighed separately and filled by hand into their respective feed hoppers on the chain-grate stoker. The patent double hopper system of feeding adopted is substantially that indicated in Fig. 1, d^2 being the coke feed hopper and d that for the coal, while g is the separating diaphragm. Thus, the composite feed enters the furnace in well-defined superposed layers, the coal being on top. The volatile gases given off from the latter maintain the firebrick ignition or "coking" arch in an incandescent state, thus establishing positive and continuous ignition at the point of entry on the grate. With a simple and intimate admixture of coal with coke in any considerable proportion, it has been proved impossible to maintain these essential conditions, as the arch gradually cools and misfiring occurs. The report says:—

"The proportion of volatile matter was approximately 8 per cent. that of coal only; this would appear to constitute an important element in determining the thermal efficiency of the boiler, for the reason that the hydrocarbon loss is minimized due to the reduction of the volatile matter in the combined fuel. The thermal efficiency obtained in Test No. 1 was 80 per cent. and in Test No. 2, with coal only, 61 per cent., showing a difference of 19 per cent. in favor of the combined fuel."

Other important data relating to these tests are as follows:—

	Test No. 1. Coal and Coke.	Test No. 2. Coal only.
Calorific value as fired	11,385 B.Th.U.	12,150 B.Th.U.
Fuel consumed per grate ft. hour	30.66lb.	31.66lb.
Ash and clinker, actual	16.22%	12·7%
Average steam pressure	178lb.	179lb.
Superheat temperature	486deg. F.	490deg. F.
Water evaporated per hour ..	10,505lb.	8,747lb.
Water evaporated per sq. ft. of heating surface	5·22lb.	4·35lb.
Water evaporated per lb. of fuel as fired from feed temperature	7·18lb.	5·76lb.
Water evaporated from and at 212deg. F.	9.22lb.	7.44lb.
Efficiency: boiler and superheater	69·9%	58·12%
Efficiency: boiler with economiser	79·96%	60·96%
Draught over fire	0·25in.	0·25in.

In simply changing over from coal only to coal and coke the economies which accrue are far greater than those which can be calculated from known losses. In all probability the increased efficiency follows largely from the fact that the size and type of furnace, and the disposition of the boiler heating surfaces relative to the fuel bed, are better suited to the character of combustion and flame length obtained with the combined fuel. The necessity for using coal of a bituminous character at all arises out of the difficulty of securing, under ordinary conditions of natural draught, satisfactory and continuous ignition if coke is used alone; but it is gratifying to note the experiences of some power station engineers who, by means of the "sandwich" system, are now using with unscreened small coke very inferior coal slack from Somerset and other collieries, which is useless for any other than direct fuel purposes, and are obtaining satisfactory results at high rates of combustion. These experiences suggest the possibility of utilizing as a "primer" for coke by means of this system such waste fuels as are now discarded in the pits, and also bituminous "duff" and washery slurry, which are now regarded as so much waste material. In the event of coal distillation schemes progressing, as it is to be hoped they will, creosote, pitch, or crude tar may become available for this purpose, while the supplies of coke would also be largely augmented.

Fig. 2 shows a modified arrangement of the "sandwich" system designed, by means of a third hopper d, to feed an additional layer of coal next to the grate, so that in burning non-bituminous or anthracite coal the grate is protected from the intense local heating effect of such fuel. Fig. 3 shows the system adapted for use with reciprocating ram-type stokers in which the feed ratio of coal to coke is more conveniently effected by a lateral, instead of vertical, movement of the diaphragm. In operation the most effective ratio of coke to coal is determined by a process of trial and error; it is then necessary only to feed the coal and coke into their respective hoppers as required.

Wheel Failures*

Wheel failures or defects which justify renewal are as follows:

Sharp flange or worn flange, shelled out, burnt chill, either from sliding or from brake application, worn tread, worn through the chill, chipped flange, chipped rim, etc. The most common cause for removal is worn flanges, next worn tread, tread worn hollow, then brake burn, brake slid, shelled out, worn through tread, cracked flanges, etc.

Worn or Sharp Flanges.—There are several reasons for worn flanges, one being the mismating of wheels when first mounted. When cast wheels are first made at the foundry, one of the first things done after the wheel is cleaned is to measure the circumference and mark the wheel accordingly. This is called "tapping," and the sizes marked on the plate of the wheel are called tape sizes.

Wheels whose tape sizes do not correspond should not be mounted on the same axle.

Another reason for sharp flanges is that the truck may be out of square. When this is so, the wheels do not track properly. One wheel runs ahead of its mate, consequently the flange hugs the rail, resulting in undue amount of wear on the flange of one wheel.

Another cause for sharp flanges that car repairers can do much to rectify is found in the side bearings. If the car rests heavily on the side bearings, the truck is not able to adjust itself readily to the tracks. Too much space between the car body and side bearing will cause the car to sway. This swaying also is very bad on the trucks, axles, wheels and rails.

Worn Tread.—Worn tread is first cousin to the sharp flange. Worn treads may occur from the same causes as sharp flanges. Examination of a pair of wheels, one of which has a sharp flange, is very likely to disclose a companion wheel with a worn tread, because the wheel having been run in one position grinds out the tread either from one wheel being larger than the other or because of the truck being out of square. There is one other cause which will produce these defects, and that is the wheels are not mounted equidistant on the axle. This not only inclines the wheels to crown against the rail, but it also brings an extra amount of wear on the journal collars.

Brake Burn or Burnt Chill.—A wheel that is brake burnt is easily distinguished by cracks across the tread of the wheel. Sometimes these cracks are only hairlines and at other times there is a distinct separation of the metal, a sixteenth of an inch or more in width, covering the entire periphery of the wheel. This is caused by the brake application continuing for a long period, heating the tread of the wheel. This causes the iron to separate on acount of the expansion of the metal.

Brake burns occur in some classes of equipment more frequently than in others, for instance, fast refrigerator line cars. These cars are designed for 60,000 pounds capacity, and are equipped with 4¼ by 8 inch axles and 625 pound wheels. This class of car is not in the same kind of service that a 30-ton merchandise car is, but on fast freight service. The speed at which these trains move is much faster than that of the ordinary freight train, consequently when it is necessary to stop the train there is a longer application of the brake. This naturally generates heat on the tread of the wheel and, as a result, brake burns and broken plates occur more frequently. If the design of the wheel does not provide sufficient metal to take up the heat, the tread is caused to expand, and as the tread expands the hairlines occur on the tread. Many times a burnt chill is passed and reported as a shell-out but there is a decided difference in appearance, likewise a decided difference in the cause. Wheel makers argue that a shell-out comes from a small brake slide leaving a small flat spot on the tread of the wheel, the subsequent pounding of the edges of the flat spot causes the metal to break away all around the spot, producing a shell-out spot. By railroad men a shell-out is considered a maker's defect and subject to replacement by the manufacturer.

Cracked plates.—Another frequent cause for wheel removals is cracked plates. The cause of cracked plates is the expansion of the tread through heat generated by the brake shoe. The heating of the tread produces a strain on the wheel, at the juncture of the front and back plates.

Brake Slide.—This generally marks the end of the wheel's service. A brake-slid wheel can do more damage to equipment and rails than any other wheel defect. The continual pounding of the flat spots on the rails will loosen every bolt in the truck, and broken rails are very often traced back to brake-slid wheels.

Worn-through chill spots have a close resemblance to brake slides, but are easily distinguished. The brake slide will have a flat spot with more or less sharp edges, whereas worn-through chill will have the edges worn over or rounded, leaving no well defined flat spot. Worn through the chill is clearly a maker's defect, and one that cannot be told by inspection of the wheel when new. The wheel when made may have a much thinner chill on one side of the wheel than on the other, and there is no way of telling this except by breaking the wheel.

A very comon cause for brake slides—and the causes are numerous—is defective brake rigging, due largely to lack of inspection to the air brakes. Another is the angle at which the brake shoe is hung from the truck, that is to say, if the angle of the brake hanger in relation to the wheel is too great, the shoe will, on one pair of wheels in the truck, lock against the tread of the wheels producing a tremendous leverage, while the other pair in the same truck will have but little leverage according to the direction the wheel is revolving. This can be remedied in nearly all cases by bringing the hanger closer to the wheel, lessening the angle.

The liability of wheel failures has increased greatly on account of the extra duty placed upon the wheels. Cars have greater capacity, trains run at increased speeds, high speed brakes, etc. The safety of every train is dependent upon the performance of every wheel in the train. The number of accidents, the safety of the traveling public, and the successful transportation of freight depends largely on the careful inspection of each wheel under every car, so that defective wheels may be discovered and removed before there is possibility of accident. The inspector should take no chances on a defective wheel nor, at the same time, cause the removal of a wheel which is in the safe limits of good practice.

* Abstracted by the *Railway Review* from a paper read before the Car Foreman's Association.

Benguet Road under construction. Cracker Line

Second Falls of the Magoapic River.

Construction Camp No. 4, on the Benguet Road

Transportation in the Philippines

Road Building Through Mountainous Regions of the Archipelago

By J. F. Springer

Of all the possessions of the United States, the Philippine Islands are perhaps to be rated as the one about which the bulk of Americans know the least. These islands constitute an archipelago of something over 3,000 different units. About 90 per cent of this number has an area of less than one square mile each. There are some 300 or thereabouts which are of considerable size. The great leaders of the entire archipelago number just two. These are Luzon and Mindanao. The total area of the land surface of the entire group is about 115,000 square miles. The population runs up to something like 8,000,000. This is about seven to the square mile. It may be gathered from the foregoing that the development of the resources of these islands will be governed largely by the prior and concurrent development of transportation. Whatever the population produces in excess of what is used at the exact points of production must be hauled by some system of transportation, and by "system of transportation" I mean something adequate—not pack animals nor human beings, but power-driven or animal-drawn cars and wagons. Seven people on one square mile of territory may get along in so far as the seven are concerned and the products of the one square mile. But, if material civilization is to play an adequate part in their life, they can not contribute to many other people nor receive from these others without one or more modern systems of transportation. This remark is especially emphasized by taking into consideration the relation of the archipelago to the rest of the world. In short, if the islands are to become a part of the modern world, then there must be public highways and railroads together with a generous supply of suitable rolling stock. The highways are perhaps more urgently needed than railways as the distances are, in general, short.

The interest of the United States in this possession centers more, perhaps, in what may be produced on the islands and shipped to America than on what may be bought in America and transported to them. It will be a long time before there will be sufficient purchasing power among the 8,000,000 to attract much attention. But the possibility of adding to the supplies needed for home consumption is something that may be made noticeable almost at once.

Thus, the nipa palm is a possible source of sugar. Other palms also are possibilities, but this particular variety is said to have very great advantages over the others. The stalk supplying the sap which yields the sugar is not a tall affair but a growth rising only two or three feet from the ground. Here is a harvesting advantage. In the Philippines, this palm is already actively growing over wide areas of tidal swamps. Such regions are its proper habitat. Low lands subject to periodic overflows of salt or brackish water are the localities where it thrives. The Philippines have, in addition to the proper climate, large areas of the required type of land. In fact, nipa palm sap has already been utilized on a considerable scale as a source of alcohol. Thus in the calendar year prior to the outbreak of the Great War in Europe, the Philippines supported about seventy-five modern distilleries producing in the neighborhood of 2,500,000 gallons of proof spirits. It should be seen, then, from the foregoing that there is a possibility of adding considerably to the world's sources of sugar, seeing that in addition to undeveloped lands the districts tributary to the distilleries will become available for sugar from the beginning of the operation of the Eighteenth Amendment. The development of the sugar lands, will, however, depend in part upon the adequacy of the highways. There must be enough roads of modern quality. This means road construction from the swamps inland, and main arteries running to the ports of shipment. That the grade of sugar is reasonably high may be gathered from the claim that the sap compares very favorably with cane or beet juice. There is a sucrose percentage of about 15, and the apparent purity averages 85. The impurities are mostly inorganic salts, sodium chloride (common salt) being the chief. There are said to be no obstacles to the production of an excellent quality of sugar by centrifugal machines. The mechanical handling of nipa sap may, with minor modifications, be carried out with the same plant as that used with cane juice. It is estimated that about 1,150 acres of swamp land are capable of supplying a factory having a daily capacity of ten tons of sugar. As to cost—pre-war data—the sap at the mill is estimated to cost not more than $5.50 to $6.00 per 1,000 gallons. One thousand gallons of sap will produce nearly 1000 pounds of centrifugal sugar with a polarity of 96 degrees. There is no grinding. The sap is obtained by cutting away the fruit at an early stage and arranging a suitable receptacle underneath the cut end of the stalk. The flow of sap continues for, say, ten weeks, on the average, and one stalk yields in this period about ten gallons of the sap. Some 800 palms grow on an acre of land. Altogether, the sugar business would appear to form a considerable item in respect to the justification of expenditures on highways.

What has been said relative to sugar applies in greater or less degree to a number of valuable products; such, for example, as cocoanuts, rice, vegetable and essential oils, and manila hemp.

The materials for road building are close at hand. Perhaps the most important is cement. The Philippine Bureau of Science has studied the possibilities of manufacturing Portland cement on the islands. The result of these studies is that a number of points have been located where the manufacture of this cement may be carried on with advantage. Thus, on the Visayan Islands, particularly in Cebu Island, there is in considerable quantity an impure limestone of coral origin, which has a composition approximating that of a suitable raw mixture for Portland cement. This is important from a road-making point of view. Moreover, this limestone is quite soft and may be excavated without removal of overburden. These considerations tend to the reduction of cost. Furthermore, the slight amount of clay necessary to bring the natural limestone to a proper Portland cement mixture is right at hand at the site or sites for the plant. Even the fuel is close at hand, certain undeveloped deposits of a suitable coal being only a few miles away. This coal could be used with rotary kilns. Moreover, the Cebu location is advantageously situated for inter-insular distribution. In addition to this location, "there are in the Philippines abundant and widely distributed formations of practically pure crystalline limestone. With these are usually to be found suitable siliceous materials for a cement mixture—such as clay, shale or volcanic tuff."

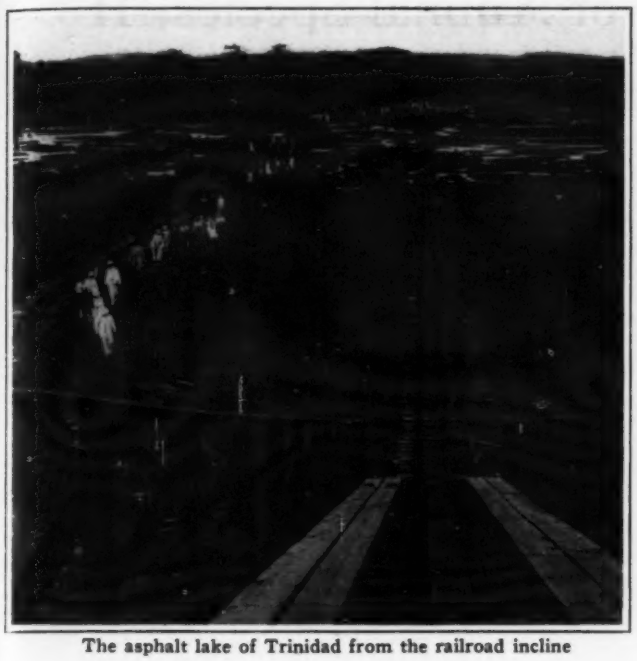
The Philippines be furnished with an adequate system of highways, because of the needs of internal commerce and because of the necessity of an export trade, but the archipelago itself possesses in abundance the raw materials for the most expensive item in the construction of modern concrete roads.

Of course, there have probably been some kind of roads here and there throughout the islands ever since any degree of civilization began to exist there. The Spaniards who preceded the Americans in control naturally executed some necessary work of this character. The Philippinos naturally participate in road construction, but just as naturally the nation in control will impress the work with its own conception of the proper thing and of the proper way to construct it.

Under present circumstances, three classes of road are being constructed. First-class roads are well graded and surfaced and provided with a thorough system of drainage. The streams and valleys are crossed usually via culverts and bridges that are complete and permanent. Generally, at points where there are no bridges across streams, a ferry is available competent to accept an automobile of two tons weight. The first-class road is usable at all times, except perhaps during a typhoon period. The second-class road is fairly graded and only partially or naturally surfaced. It is not adequately maintained at all times. The bridges and culverts may be complete in most cases, but they are in part of temporary construction. Only the dry season can be counted on as a period of complete availability. The third-class road is one not admitted to the first and second classes. It may thus range from a tolerably good road down to one that is almost unusuable except under favorable conditions.

Of course, road construction turns on the amount of

(*Continued on page* 339)



The asphalt lake of Trinidad from the railroad incline

Thousands of barrels of asphalt ready for shipment from the refinery

Where the Asphalt Comes From

The Production of Road-Building Material from the Great Lake of Trinidad

Photographs copyright by Publishers Photo Service.

Long ago when Dame Nature was stocking her wonderful storehouse with gifts for man she must have recognized our modern day needs for smooth and dustless highways. For down in the crater of an extinct volcano she set up her chemical laboratory and started it to work producing an inexhaustible supply of asphalt, the perfect road material. Nature is not always kind to man; many of her treasurers are hidden deep down in the earth, or at the bottom of the sea. For copper, tin, and gold man must climb high mountains, and drill and blast through miles of rock; not so with asphalt, however, for here nature seemed to have been in a pleasant mood. "Let's make it handy," she seemed to say, and handy it is. Near the sea it lies, and right on the surface so that no mining is necessary—in a form so pure that it requires almost no refining and in a constantly renewed supply. What other mineral can you name, which when a wagon load is taken away accommodatingly fills up the hole by itself, so that there is just as much there as before? Sounds like a story of mythology, yet asphalt does just that. The largest and best known asphalt deposit in the world is found on the eastern side of the island of Trinidad just a few miles off the coast of Venezuela, South America. This great deposit has been worked for years at the rate of 200,000 tons a year, yet there is no hole to be seen, not even a depression in the bed and, apparently there is just as much there now as there was at the very beginning.

The "Pitch Lake" as it is called, occupies what seems to be the crater of an extinct mud volcano. It is about a mile from the seashore, and has an elevation of 135 feet above the sea. The "lake" or deposit covers an area of about 100 acres, and is of an unknown depth. Borings of a hundred feet have been made. The surface is hard excepting a few soft spots near the middle; it resembles brownish black earth or stone. In places it is a bit soft underfoot so that the shoes leave impressions in the surface just as they do on an asphalt pavement of a hot day.

There are a few soft spots where the mass oozes and bubbles up in a semi-liquid state. There is no vegetation over the deposit, and standing at the edge one notes that it is preceptibly higher in the middle than at the sides.

The deposit is owned by the Government of Trinidad, and is leased to an American company to work. The income to the Island from this curious deposit is said to amount to around a quarter of a million dollars annually.

A refinery is located near the edge and several narrow gage tracks run out across the lake. The cross ties of these tracks must be renewed every few weeks, for they gradually sink down and disappear in the asphalt and if new ones are not constantly supplied the track itself would soon go out of sight. Negro workmen dig up the crude asphalt with picks in the spots where it is hard; the soft spots are left alone. It does not come up easily but is rather tough, bends but does not break easily. The mass below the surface is full of holes and reminds one of Swiss cheese. The further down we go the softer does the material become, so that after one spot is dug out to a depth of about two feet or so, the workmen are obliged to dig in some other place. In the course of a week or ten days the hole that was dug out fills itself up again even with the surface. The heat is intense over the whole surface of the lake.

This asphalt contains very little foreign matter and as it stands could be used for road work. When it is to be used for roofing or the making of asphalt paints it is put through a special refining process.

Asphalt or asphaltum is like coal, a product of prehistoric vegetation. The only other deposit which approaches this one in size is found in the lowlands of Venezuela about fifty miles from the coast, and although of a still purer quality the location of the lake makes it hard to get at. Some authorities claim that these two lakes are connected, and are fed from the same source through subterranean fissures in the rock.

Asphalt was first used as a road material in Paris some fifty years ago, but has attained its greatest usefulness in America.

Loading the cars with asphalt from the lake

Digging up the surface of the asphalt lake

Posture as a Factor in the Origin of Animal Species—II*

The Embryological and Heredetarian Aspects of the Case

By Edward Perrier, Director of the National Museum of Natural History, Paris.

The changes in attitude which we have enumerated have been capable of frequent repetition in various epochs in organisms of similar nature; they are more or less recent; and from this proceeds the gradation which enables us to arrange them in series, in the forms of the present day; they have been able to produce various secondary consequences according to circumstances; but the conviction which results from their comparison of these forms is that they were not imposed in the very beginning upon the organisms which exhibit them, but that the latter had recourse to them under the pressure of circumstances in the conditions of the environment in which they live, or even merely because of a modification in their comparative specific gravity, so as to obtain a more commodious existence and assure themselves of the maximum amount of well-being. These changes were temporary at first, they then became distinctive, and finally hereditary.

Even in the ancestral series of animals of the present time it has been possible to produce many successive changes; each of these has left its trace, heredity must have preserved the phases, and hence we ought to be able to perceive these in the embryonic evolution of the types we are considering. This is just what happens, in fact, and is that which gives a definite significance to the information which this evolution furnishes as to their origin. We must now examine this side of the question.

THE ROLE WHICH HAS BEEN PLAYED BY ATTITUDES

Cuvier placed the starfish, the sea-urchins, the holothurians and the crinoids in his division of the zoophytes by reason of their radial structure, which he compared to that of the Medusae, a simple florescence of arborescent hydral polyps; there is, however, nothing in common between the complicated organization of these animals, which he considered a simple class of zoophytes, and the Medusae; consequently most of the naturalists since his time have raised the order of the echinoderms to the rank of a species. But whence comes this species composed of animals having a special kind of organization, one of whose most remarkable features is an irrigation apparatus whose function it is to introduce sea water into their economy? The science of embryogeny will give us the answer.

At the end of the first stage of its evolution the embryo of an echinoderm often assumes quaint and curious forms (the Brachiolaria and Bipinnaria among the starfish, the Pluteus among the Ophiura, and the sea-urchins). These forms (which are of the same type) are at first perfectly symmetrical and are related to the more simple forms of the embryos of holothurians and of crinoids, which are quite obviously paramount to annelid worms having bodies composed of only five segments. The digestive tube is itself symmetrical and bears two lateral sacs which are also symmetrical; but these internal organs very soon become dissymmetrical; the two symmetrical sacs mentioned above as borne by the digestive tube begin to roll themselves around the latter as if the young animal were twisting itself like the spiral of a screw. However, since it continues to swim it retains its external symmetry, nothing being changed so far as regards its relations with the external medium.

It can not be this medium, therefore, which has occasioned the torsion of the internal organs; this can be due only to a heredity whose effects have been dissociated by reason of the precocious evolution of the digestive tubes, and which has not been followed by the external forms, which have been retained by reason of the maintenance for the embryo of the primitive kind of life. The course of evolution corroborates this explanation.

In the course of one transformation after another the left side of the embryo becomes the abdomen of the complete echinoderm while its right side becomes its back. It is impossible if we go back into past history to explain this singular metamorphosis otherwise than by saying that the ancestors of the echinoderms were worms who were in the habit of lying upon their left sides. But what could have been the cause of such a phenomenon? It seems probable that the cause may be found in a character of physiological nature which is common to all the echinoderms and to which indeed they owe their name: that of precipitating calcareous matter in their tissues in such quantities that their surface is frequently covered with spines and that their movements are no longer possible except in a mass, like those of the sea-urchins—at any rate unless the calcareous matter is collected into joints capable of being moved upon each other by means of muscles as in the starfish and the chinoids, or else dissociated into small spicules as in the holothusians.

The future echinoderm was at first a soft and translucent worm whose body was composed of five similar joints, a form which is reproduced to-day in the primitive embryo. This worm was a swimmer and lived in the deep sea. The deposit of lime in its tissues having made it very heavy and at the same time immobilized it, it was drawn to the bottom by its comparative weight.

But a worm which is at rest generally curves itself into the shape of the letter C because of the greater strength of its ventral muscles. This habit is exhibited daily at the present time in caterpillars, white worms, the larvae of cockroaches and various adult animals (the wood-louse, *Glomeris*) and it even occurs in an exaggerated form in certain mammals (hedgehogs, tatous). The lime in the echinodermic ancestral worm hindering it from straightening itself the animal accommodated itself to this condition of affairs by placing its mouth against the soil from which its nourishment is derived and directing its anus upward, at the same time contracting its body into a curved shape; from this was derived its helicoidal winding and its posture of lying upon its side.

It is probable that the ancient cystids, sea-urchins and their descendants, the holothurians, stopped at this point, merely simplifying or complicating in detail the spheroidal body resulting from the single winding of the original helix and retaining the helicoidal arrangement of the digestive tube only internally. The same thing is true of the crinoids, whose organization is almost that of the sea-urchin around which there have sprouted five simple arms (*Eudiocrinus*) or five branching arms (*Antedon*, etc.), but in the starfish the primitive helicoidal intestine is compressed like the shell of the sea-urchin into a single sac.

But the various segments of the worm possess the faculty of budding and we have seen why this faculty is exercised only in the front end in the worms which crawl. These reasons no longer exist; each of the segments of the rolled up echinoderm is capable of budding, hence the long arms which constitute the starfish and which are also produced in the crinoids, though in a slightly different manner. I have demonstrated elsewhere that these arms each of which is symmetrical with respect to a longitudinal plane, are still ringed like the body of a worm in the primitive starfish (Brisinga).

Because of being protected as a general thing by a shell the molluscs appear to be even more isolated than the echinoderms. But there is a group among them which goes back to the earliest time of the Primary age and which seems from the first glance to be very enigmatic, namely, that of the oscabrions (Chiton). The study of the nervous system of the most primitive molluscs (Pleurotomaria, Fissurellae, haliotids, turbos, troques) has revealed their relationship with the oscabrions, and the latter are themselves undoubtedly related to the annelid worms; they do not possess a shell properly so-called, but the back is protected by a series of eight similar plates forming an integral portion of the teguments to such a degree that in certain species each of them bears eyes, thus establishing the fact that the body of the molluscs was originally segmented and that these animals are nothing other than a special form of annelid worms whose tegument was fitted for secreting lime. But that which differentiates the other molluscs from these worms is the fact that the body is all of a size and that the viscera are concentrated in a dorsal protuberance which remains elongated into a cone in the swimming molluscs like calmars and the octopus, but which is rolled into a helical form in the climbing molluscs like the snails. This protuberance disappears indeed in the molluscs which have bivalve shells like the oysters, but no one can deny that these creatures are of the same type as the climbing molluscs, and moreover the disappearance of the dorsal swelling merely brings back to the normal condition, under the action of gravity, animals which had been rendered monstrous in form by the same gravity in consequence of a posture which was unnatural, as we shall see.

The first thing to be explained in this problem is how a dorsal swelling could be produced upon the back of such an animal as the oscabrion. If the hypothetical descendants of the latter had retained its posture, it is clear that the only action of gravity would be opposed to the production of such a deformity. A dorsal protuberance would quite naturally be formed on the contrary upon the back of an animal swimming upside down, with the belly upward and the back downward, held by a powerful float near the surface o fthe water and having the dorsal tegument made heavy by solid plates and, therefore, attracted by gravity. The formation of this protuberance would have upset the arrangement of the plates of the ancestral chitons and the whole economy of their organism except with respect to the ventral surface. The oscabrions are related to the Pleurotomaria, in fact, by the nervous system which is connected with this surface.

Two types of molluscs must have been produced almost simultaneously: that of the castropods in which the ventral sole has remained highly developed, being used for swimming; and that of the cephalopods in which the ventral sole is reduced to the circumference of the mouth and which swim backwards forcing the water suddenly from the respiratory chamber. In both forms the dorsal cone begins by being straight and possibly the eight triangular plates which constitute the hitherto inexplicable pyramidal shell of the Conularia correspond to the eight plates of the oscabrions; but besides this the shell which covered it was always conical and in one piece (*Tentaculites* among the gastropods, *Orthocera* among the cephalopods.) Such a shell probably indicates that the animals which it protected were floating, they did not have to climb bearing such a steeple upon their back, and this tower sometimes attained a length of two meters in the *Orthocera*. It was inhabited, moreover, only in its upper portion by the animal, which cut itself off from the empty portion by a partition traversed only by a tube resulting from the withdrawal of the tegument attached to the apex of the cone; a new partition being formed at each stage in the growth of the animal. This can still be seen in the chambered shells of the nautilus and the spirules of our warm seas.

The straight shells were quickly succeeded by symmetrical shells rolled into a spiral form. This winding shape was evidently the consequence of the resistance exerted upon a swimming animal by the surrounding water; it must have been produced in the direction from the rear to the front so as to uncover the respiratory chamber of the animal, which is situated at the rear. The spiral shells of the Bellerophons correspond to this phase in the gastropods; the slit which this shell exhibits indicates that the animals although at first remaining swimmers gave rise when they became climbers to the Pleurotomaria, which still live, and the series of the scutibranch gastropods (Fissurellae, haliotids, etc.) which lead by way of the turbos and troques to the ordinary gastropods. But in order to climb the primitive gastropods which swam with the abdomen in the air must have reversed their attitude; thereupon the pressure of the surrounding liquid would tend anew to overturn the shell upon the orifice of the branchial chamber remaining at the rear; the animal must have brought this forward by contracting one-half of its body more than the other, in order to make it revolve; in this manner it became dissymmetrical; and the spiral winding was succeeded by the helicoidal winding. The present classification of the gastropods is only a panorama of the successive phases through which has passed the reduction of the contracted half of the body with respect to the other. Embryogeny confirms all these conclusions. The embryos of all the marine gastropods are swimmers; they swim with the belly upward and the back downward like the Carinaria and the Ianthina; their primitive shell is symmetrical and has its apex curved forward above the head; it must twist in order to become what it is in the adult stage. The embryo of the bivalves is also a swimmer; in this group the dorsal cone being abortive the animal has remained perfectly symmetrical and the two valves of its shell correspond to the two halves of that of the Bellerophons separated by the slit, which is still retained in the pleurotomaria, which have become dissymmetrical.

It remains to explain the origin of the vertebrates of which the Tunicate are merely a simplification. Ever since the embryogenic researches of Alexander Kowalevsky, it has been accepted as a fact, almost without dispute, that the Amphioxus was the common ancestor of the Tunicata and the vertebrates. The latter, as has been shown by Armand de Quatrefages, already exhibits all the essential characters of the vertebrate; no oesophagal collar, a central nervous system situated entirely above the digestive tubes; centres of circulation placed below; a dorsal cord of connective tissue between the central nervous system represented by the spinal cord and the digestive tube. But the descendants of this primitive or rather, we may say, precursory vertebrate followed two very different paths in their later evolution.

* Translated for SCIENTIFIC AMERICAN SUPPLEMENT from *Scientia*—Bologna.

Some of them became attached to the ground by the head and because of having no use of their locomotor organs they became so highly simplified that naturalists scarcely recognize them as being connected with the molluscs. The others on the contrary underwent a high degree of development, became free, and formed the great division of the vertebrates.

Let us examine first how the plan of the vetebrates was realized in the Amphioxus.

Etienne Geoffroy Saint Hilaire had already observed that in order to show the resemblance in the plan of the vertebrate animals to that of the articulated animals, it was only necessary to turn them over on their backs; *i. e.*, to invert the posture; he even attempted to discover more exact homologies between the two types, assisted in this by the physicist Ampère who was much intrigued by this comparison. The idea was correct in itself; but it is with the annelid worms that vertebrates are connected instead of with the insects and the problem itself should be inverted; it is not concerned with discovering what parts of an annelid may be equivalent to those of a vertebrate but rather with how a vertebrate can be derived from an annelid worm.

The main characteristic of the vertebrate and the one which places it at the head of the animal kingdom is above all the great development of its nervous system which has in its turn stimulated the development of the supporting apparatus called the dorsal cord. Besides its great volume the nervous system of the vertebrate is also distinguished by the absence of the oesophagal collar which exists in all the other Artiazoa and which originated in the development undergone by the sensitive elements surrounding the mouth because of their continual stimulation by the passage of food. Consequently any acceptable explanation of the origin of the vertebrates must comprise that of the disappearance of the oesophagal collar. It is very evident that when an organ has acquired in the adult animal proportions which are comparatively large with respect to the other organs it is obliged to develop more quickly than these in order to attain its proper proportion at the same time as the other organs. The development of the nervous system will therefore necessarily be peculiarly precocious among the vertebrates, and in anterior extremity, that which comprises the oesophagal collar and the brain and which is the greatest in volume, must necessarily be especially advanced in development. But all this development is accomplished at the expense of the exodermis and necessarily so, since it involves the oesophagal collar, not only upon the ventral surface, but in the very region to be occupied by the mouth, whose development is always slow. The rapid development of the anterior extremity of the nervous system, *i. e.*, its cerebral extremity, would inevitably cause it to take the position of the mouth, which must herefore be formed elsewhere.

But what will be the outcome of this conflict between the mouth and the brain? We have no need to formulate hypotheses upon this matter, for the embryogeny of the Amphioxus gives us the answer to the question. The adult animal possesses respiratory slits which bring the digestive tube into communication with a peribranchial cavity of late formation, so that in the embryo these slits open directly outward; they make their appearance successively. As soon as the first is formed the young animal uses it for a mouth. This secondary mouth no longer has any connection with the nervous system; there is no opportunity therefore for the formation of an oesophagal collar, and since the two symmetrical slits are not formed simultaneously, and even if they were so formed the embryo could not use but one of them, the branchiobuccal slit is lateral. Moreover, since the animal's food is always found upon the ground the animal is obliged to lie upon its side and become pleuronectic like the soles in order to seize it; and this in fact is one of the phases through which the Amphioxus passes in the course of its development. Later on it buries itself in the mud; conditions thereupon once more favor symmetry; we now see a sort of shutter or curtain descend upon the lateral mouth starting from that edge of it which is nearest to the nervous cord and covering it almost entirely, leaving free only a median slit situated opposite the nervous system, *i. e.*, upon the median line of the former ventral phase.

When the descendants of the Amphioxus ceased to bury themselves in the sand and began to live in a state of liberty they were obliged to turn the mouth toward the ground in order to feed themselves readily and since we give the term ventral to the surface of the body which is turned toward the ground and which bears the mouth the nervous system became dorsal instead of ventral: thus the inversion of posture imagined by Geoffroy Saint Hilaire is an actual fact and we have here explained both its cause and its mechanism. Only Geoffroy compared the vertebrate with the arthropods, while everything indicates on the contrary that they are related to the worms.

It is worthy of note that Dohrn had already clearly established the fact that the mouth of sharks is connected with the branchial slits (gills), but he considered this to be the result of the fusion of two branchial apertures, whereas a single one is sufficient. At this point it may be asked what is the origin of the branchial slits themselves; we may recall merely that they exist already in the digging worms of the Balanogloss genus which cannot be, however, placed among the vertebrates because of the extreme reduction of their nervous system and the lack of segmentation in their body. Lateral communications between the digestive tube and the exterior medium are also found in certain opisthobranch molluscs and certain Planaria; these communications, therefore, appear so frequently that they may have appeared in the annelid worms, which have now disappeared, that were the ancestors of the vertebrates.

The body of the vertebrates is in fact quite closely segmented. In the embryos of the higher vertebrates the internal segmentation appears indeed to be limited to the dorsal region and thence it has been concluded that this was not a true case of segmentation. But this incomplete segmentation is simply the result of a phenomenon of embryogenic acceleration. The intersegmentary partitions were complete at first, in fact, in the embryo of the Amphioxus, and it is only secondarily that their ventral area disappeared and that a continuous ventral cavity was formed. We know, moreover, that the researches of Semper and of Balfour have established the homology of the primitive renal canalicules of the vetebrates and of the segmentary organs of nephridia of the annelid worms.

The origin of the vertebrates, therefore, may be explained in a manner analogous to that which concerns the molluscs and the echinoderms; from this higher species the Tunicata became detached.

The history of the Tunicata is peculiarly instructive, but in another direction. The structure of the embryo and its dissymetry are to be explained by what we have said in regard to the Amphioxus. Their degeneration after fixation and their protandric hermaphroditism are phenomena of a general nature to which it would be interesting perhaps to revert; their recovery of the faculty of budding when their simplification had become sufficiently marked causes them to behave like the Phytozoa, but here the embryogenic acceleration has had an unexpected consequence. A precocious metamorphosis having caused the larvae to lose their organs of fixation certain Tunicata have again become free and swimmers without losing the faculty of budding, though modifying it: in this way were developed the Pyrosomes, the Salpoe and *Doliolum*, at the same time that the phenomenon occurred of alternating generations—that curious phenomenon whose discovery gave to Chamisso as great a reputation as a naturalist as his story of Peter Schlemihl, the Man Without a Shadow, gave him as a novelist.

Doubtless the transformations I have here referred to may at first glance appear to be extravagant, but this comes from the fact that we are accustomed to see about us only recent transformation of but slight extent. Here we are concerned with a fact: there are in the animal kingdom at least eight types of forms which at first sight appear to be irreducible. At least, unless we reject the idea that animal forms have undergone gradual evolution—which would seem impossible in the present state of our knowledge—we are bound to believe that the enormous differences which separate them have been gradually arrived at and that they are due to natural causes alone. In the presence of the accomplished fact it would be futile to deny the strength of these causes, and discoveries in embryogeny which are not to be challenged exhibit them in operation in a past which is too remote to allow any opportunity for any experimental verification of our deductions.

But we know at least that the great divisions of the animal kingdom are very ancient, since from the earliest period of the Primary Age there already existed sponges, polyps, arthropods, worms, echinoderms, molluscs and fishes. This remote past offers support for our argument. It is evident in fact that the modifications of posture with which we are concerned could have been produced only by placing the animals which exhibit them in conditions of existence which are quite certain. They could not have survived except in an environment where they had absolute security, where they were sheltered from any struggle for existence, *i. e.*, at a distant epoch when life had not yet attained the intensity which it exhibits to-day, and this is confirmed by paleontology, since it shows us all the great types already formed at the beginning of the Primary Age.

It is not exactly true, therefore, as was believed not by Darwin but by his disciples, that the struggle for life was the great instrument of variation and improvement in organisms. Their essential characters are produced externally to them in complete tranquillity under the action of commonplace internal or external causes which are still operative at the present time and which determined later their secondary characters. The natural selection resulting from the struggle for life did nothing but effect a choice among the forms already produced of the most advantageous and fix these by favoring the multiplication of the number of the individuals which had acquired them and which were thus obliged to propagate among themselves, which is the only known means of causing acquired characters to become hereditary.

If now we bear in mind that the branching forms of the sponges, the polyps, the Bryozoa, can be explained by very simple theories which may be applied both to organisms as high as those of the compound Ascidia among the Tunicata and to organisms as simple as the plants, and that the segmentary forms of the arthropods and the worms can be explained still more readily, we perceive that the veil of mystery which has so long enveloped the origin of living forms is little by little being lifted. Recent researches even justify us in believing that the origin of life itself will not always remain inexplicable. Thus biology enters boldly into the cycle of explanatory sciences.

Transportation in the Philippines

(*Continued from page* 336)

money available. It also depends upon the regularity of appropriations as well as upon their total. Since 1908—that is, about a decade after the beginning of American control—about 2,000,000 pesos has annually been put into roads by the Insular Government. This is about 6 per cent of the Insular revenue. "The provincial road and bridge fund for all provinces approximates 4,000,000 pesos per annum, making a total of 6,000,000 pesos annually for road and bridge work." Thus, the Insular Government contributes one-third of all expenditures on roadway and bridge construction. The right of way costs but little, as in general the Philippine farmer is ready to contribute it for a first-class road running through his land.

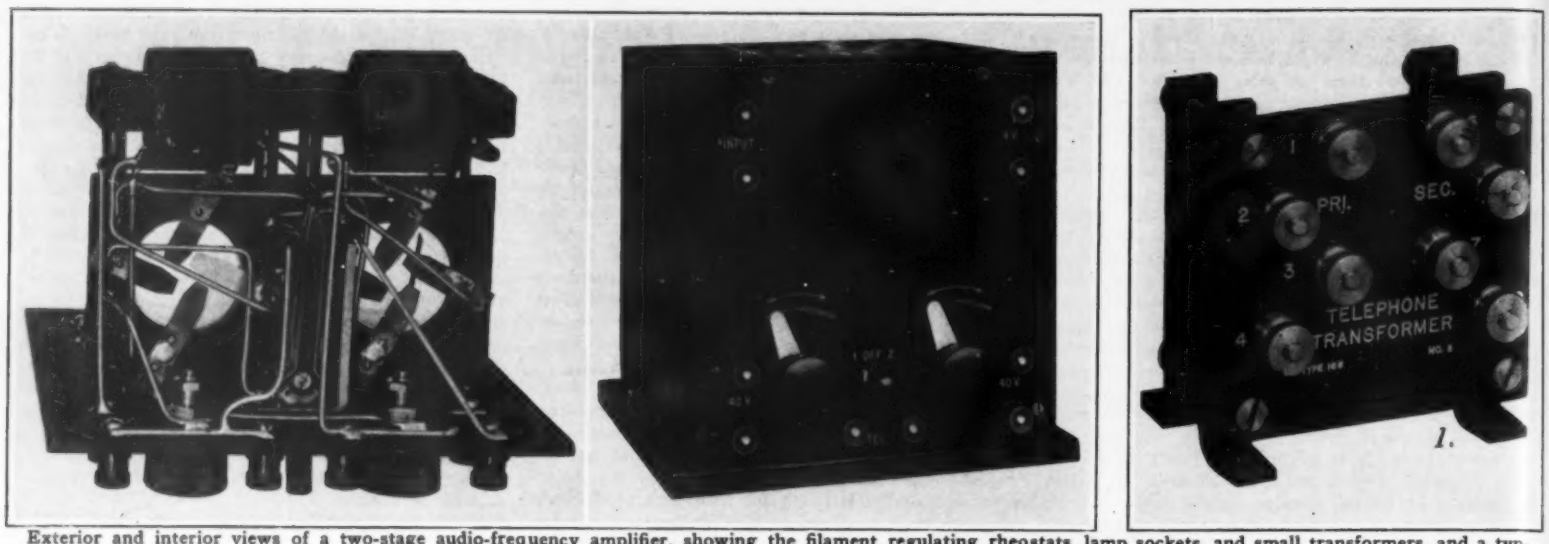
Manila is, of course, the chief point to and from which roads must run. By the completion of certain intermediate sections, there is now in existence a first-class highway connecting Manila with Nasugbu in the Province of Batangas. This is a stretch of 193 kilometers. Another first-class road connects Manila with Mabalacat in the Province of Pampanga. This is 99 kilometers long. The Manila North Road, running from Manila to the northern end of the Island of Luzon, is now presumably completed, as at the close of 1916 but two rather short sections remained to be constructed or completed.

The Benguet Automobile Road was a line of great importance as it afforded a ready means of access to mountainous regions. Thousands of people took advantage of it. The traffic was sufficient to result in the organization of a more or less regular system of automobile transportation. The Benguet Automobile line operated, in 1918, six touring cars, nine passenger trucks, and six freight trucks with two trailers. This equipment of rolling stock was not always competent to meet the full demand. Of first-class passengers transported there were 2,158; of second-class, 3,356—a total of 5,514. Naturally, passengers traveled in both directions. Supplies would, of course, have to be taken into the mountains of Benguet. Then considerable quantities of vegetables, properly belonging to the temperate zones, are grown in these uplands and are transported to Manila and other points in the low-lying regions. Further, the baggage of those visiting the mountains also furished a good deal of material to be hauled. Over the Benguet Automobile Line were transported in 1918, hand baggage to the amount of 398,168 kgs. and express and freight to the amount of 561,431 kgs. The town of Baguio in the Province of Benguet may be named as perhaps the most notable of the mountain resorts served by the automobile line.

The Benguet Road is about to be abandoned, if abandonment has not already occurred. The Naguilian Road, a newer road, replaces it in service. The last named road is already becoming the favorite as is evidenced by the fact that in 1918 a greater number of vehicles passed over it.

Benguet is a mountainous province in the northern half of Luzon, the northernmost large island of the whole archipelago. The center of the province—say, the town of Baguio—is perhaps 125 miles north of Manila, the distance being measured in an air line. The construction of a road through this region involved a good deal of hazardous work, because of the natural inaccessability of parts of the route. The workmen were at times held together loosely by a long rope. Naturally, the route twisted and turned and zigzagged in order to reach its goals by a reasonable grade. Up in the mountains levels of several thousands of feet above sea level were

(*Continued on page* 344)



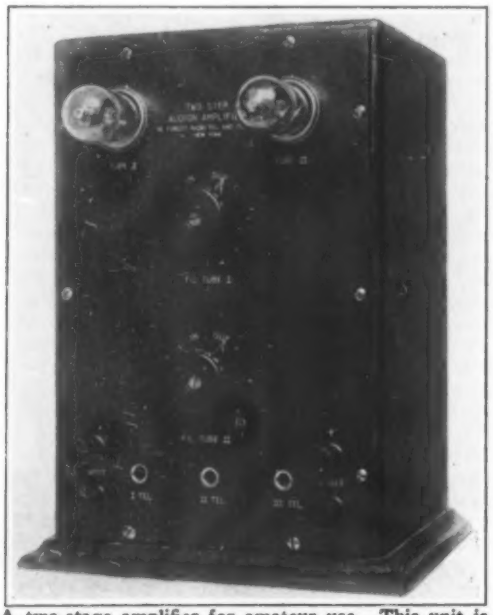
Exterior and interior views of a two-stage audio-frequency amplifier, showing the filament regulating rheostats, lamp sockets, and small transformers, and a typical transformer used in audio-frequency amplification

Experimental Wireless Telegraphy and Telephony--IX

Discussing Further the Action of Vacuum Tubes as Applied to Radio Communication

By Louis Gerard Pacent and Austin C. Lescarboura

He would be an imprudent man who would dare to prophesy what may be done with the vacuum tube in years to come. Indeed, almost every day brings forth some new possibility of this remarkable electrical development, especially in the amplifying line, where wonders have already been realized. Thus during the war the British are reported to have constructed a nineteen-stage amplifier, which enabled naval operators stationed at an English port to hear the German warships in Kiel Canal using their buzzer sets, some 300 miles away. Obviously, the Germans used their buzzer sets for intercommunication between ships lying less than a mile apart; and up till that time the buzzer was considered practicable for communicating over a very short distance, say less than five miles. So one can hardly accuse the Germans of being careless when they transmitted official orders and important messages and the usual gossip between operators with their buzzers, because they were fully justified in believing these messages well out of hearing of the enemy.



A two-stage amplifier for amateur use. This unit is controlled by a plug and jack arrangement, similar to that already described.

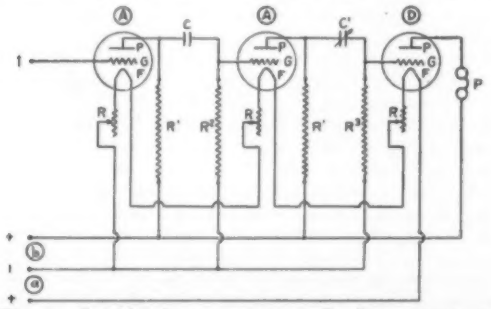


Fig. 2. Combination two-stage radio frequency amplifier and detector of the resistance-coupled type.

The leads marked 1 and — are connected with the tuning apparatus; *a* is the filament battery and *b* the plate battery. *A* represents each amplifier bulb; *D* the detector; *R*, filament rheostat; *P*, 'phone; *C*, .1 microfarad fixed condenser; C^1, variable air condenser, with a maximum capacity of .0007 microfarad; R^1, resistance of 48,000 ohms; R^2, ½ megohm; R^3, 1 megohm.

It is highly problematical just what was the degree of amplification attained by the British with their nineteen-stage amplifier. When it is borne in mind that the best three-stage amplifiers of today give an amplification of several hundred times, it is obvious that the British amplification must have been in the billions of times. Little wonder, therefore, that the faint waves created by the German buzzers were heard 300 miles away, and that the British and their Allies during the last days of the war, were able to keep in touch with the latest developments of the German fleet, as well as share in their future plans.

All of which brings us face to face with the stern realization that today there is no telling who copies our message. Even the amateur wireless operator, working his set in any part of this country, may be heard in China. Why not? It is merely a matter of proper amplification—if the results are worth the trouble involved; for that is the degree of marvellous efficiency attained by vacuum tube amplifiers at present.

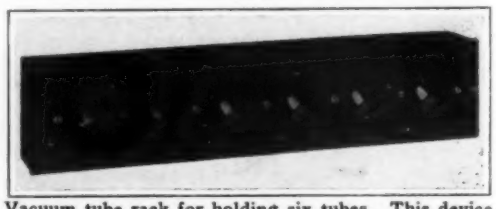
AMPLIFIERS ARRANGED WITH RESISTANCE COUPLING

Amplifiers, as described in the last instalment of this series, are not limited to radio telegraphy and telephony in their practical application. They are actually employed on all land telephone lines which are over 300 miles long; in fact, it was the development of the vacuum tube, more than anything else, that made trans-continental telephony a *fait accompli*. The vacuum-tube amplifier amplifies faithfully or without distortion, it is this quality that makes it the only amplifier suitable for long-distance telephony.

In the last instalment the audio frequency type of amplifier was described and illustrated by means of diagrams, the successive stages being coupled by means of small transformers. In many cases amplifier transformers are replaced by suitable resistances and condensers, the amplified energy being passed from one circuit to the other by means of the resistance coupling. This method is preferable in many instances because of its simplicity and because of the fact that the radio or the audio frequency can be amplified at will.

RADIO FREQUENCY AMPLIFICATION

If the grid condenser is eliminated on part of the tubes in a multi-stage amplifier, as shown in Fig. 3, then the incoming radio frequency is amplified before it is rectified, and after it is rectified by going through the detector tube it is then amplified again at audio frequency. Amplifying at radio frequencies, although it is rather difficult to do so at times, has numerous advantages and the experimenter is urged to try amplifying at radio frequencies whenever possible since one of the principal advantages of this method is that radio frequencies are



Vacuum tube rack for holding six tubes. This device is used in transmitting work.

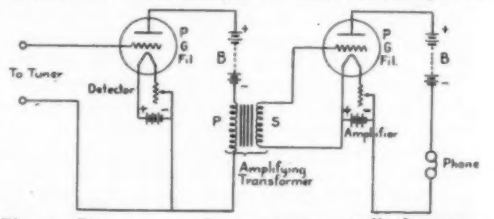


Fig. 1. Detector and one-stage audio-frequency amplifier.

Separate filament and plate batteries are not necessary, it being understood that only one battery for filament and another for the plate can be used.

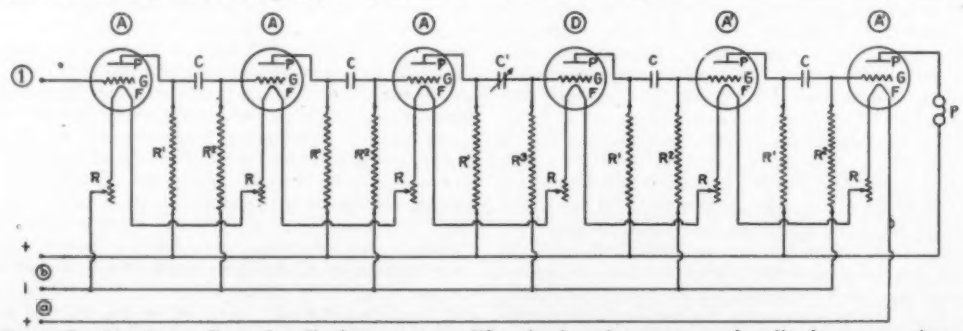


Fig 3. Combination radio and audio frequency amplifier, having three stages of radio frequency, then a detector, followed by two stages of audio frequency amplification, all resistance coupled.

The leads marked 1 and — are connected with the tuning apparatus. *a* is the filament battery; *b* the plate battery; *A*, radio frequency amplifier; A^1, the audio frequency amplified; R^1, resistance of 48,000 ohms; R^2, resistance of ½ megohm; R^3, resistance of 1 megohm; *C*, fixed condenser of .1 microfarad; *G*, grid; *P*, plate; *F*, filament; *P*, 'phones; C^1, variable air condenser with maximum capacity of .0001 microfarad.

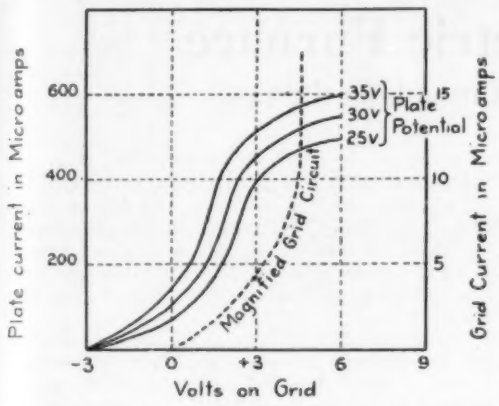


Fig. 4. Characteristic curves of a three-electrode vacuum tube.

inaudible to the human ear and the amplifying action is therefore carried on without unpleasant noises to the listening operator.

By using special transformers the transformer method can be applied to radio frequency amplification, but this is considered quite difficult at present, and the amateur is advised to use resistance coupling as shown in Figs. 2 and 3.

HOW THE VACUUM TUBE AMPLIFIES

Taking into consideration the characteristic curves of a vacuum tube as shown in Fig. 4, it will be noted that a small change in the grid voltage produces a large change in the plate current. The curve of 30 volts shows that the plate current increases from 200 to 400 microamperes if the voltage on the grid is varied from 1.2 to 3 volts. If the grid voltage is left at 1.2 volts, it will be noted that the plate current becomes 280 microamperes. By simple calculation, then, it will be noticed that a volt added to the grid voltage produces approximately seven times as much change in the plate current as would a volt added to the plate voltage. This factor, seven, which varies with different types of vacuum tubes, is called the amplification constant and determines the amplifying value of a vacuum tube. The larger the amplifying constant the better the tube operates as an amplifier.

Taking it for granted that the amplifying constant is seven, then a single-stage amplifier will amplify seven times, a two-stage amplifier in cascade would amplify 7 times 7, or 49 times, a three-stage amplifier in cascade

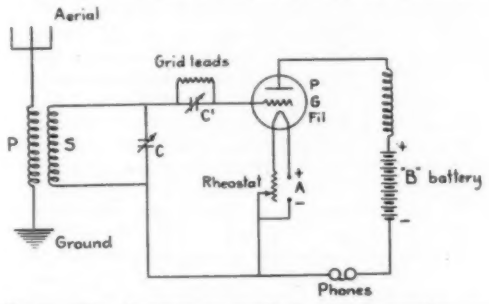


Fig. 5. The Armstrong method of regenerative or self-amplifying receiving.

would multiply the weak signals 7 x 7 x 7 or 343 times, and so on.

REGENERATIVE AMPLIFICATION

It remained for a wireless amateur, who today is Major Edwin Howard Armstrong, to discover that it is possible to increase the sensitiveness of a vacuum tube as a detector enormously by using its own amplifying action. This was accomplished in several ways by Major Armstrong, and one method of connecting a tube and its accompanying instruments is shown in Fig. 5.

The explanation of the amplifying action of a single tube, which is called the regenerative action, is quite

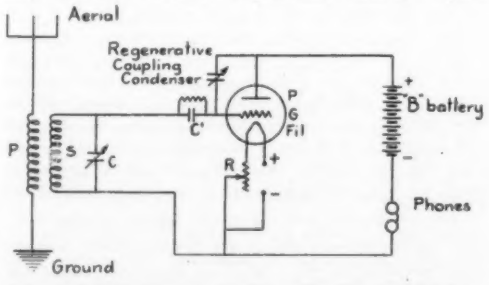


Fig. 6. Regenerative circuit showing electrostatic coupling of grid and plate.

simple. Anyone who has placed an ordinary telephone receiver against the mouthpiece of a telephone transmitter has noted the very loud and musical sound caused by the regenerative action brought about by the coupling of the receiver and the transmitter.

Now it has already been explained that the plate current of a vacuum tube is of positive oscillatory character and in exact phase with the alternating current applied on the grid, and due to its internal capacity some of the plate energy is fed back to the grid and regenerated again. This regenerated energy in turn produces a larger amplitude or height of current in the plate and therefore a larger response in the telephones.

Major Armstrong was the first man to take advantage of this action, and he went to work with a view to helping along this action. He aided it materially by tuning the plate circuit with a suitable inductance, which may be called a regenerative inductance and which helps to make the vacuum tube resonant, allowing the energy to pass freely between the grid and the plate and vice versa. Simultaneously with this amplifying action, the vacuum tube is working as a regular detector.

The regenerative action can be secured by several other methods, although fundamentally they are practically the same. Figs. 6 and 7 show regenerative action through the use of the electrostatic coupling between the grid and plate.

In Fig. 8 it will be noted that electromagnetic coupling is used between the grid and plate. In Fig. 9 is shown a regenerative circuit using the capacity of the 'phone cords and "B" battery for electrostatic coupling of the grid and plate.

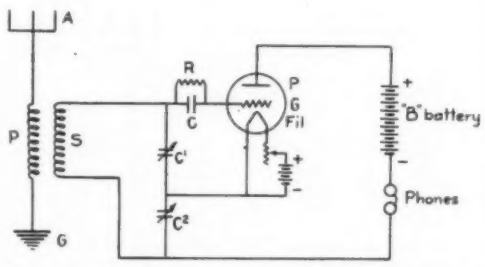


Fig. 7. Another method of regenerative electrostatic coupling of grid and plate.

THE VACUUM TUBE AS A SELF-GENERATOR

The vacuum tube can be made to generate high- or low-frequency currents of practically any desired frequency or wave length. Fig. 10 shows a simple method and indicates the coils, *P* and *S*, which, as already mentioned, transform some of the energy in the plate circuit back to the grid and thus increase the original grid voltage. Then if the coupling is made close enough to allow the voltage to feed back to the grid circuit in a volume greater than the voltage originally there, the oscillation will continue even though the original source which caused the oscillation is removed.

Various circuits can be used for generating oscillations with vacuum tubes. Fig. 11 shows a method that is considered the simplest and is thoroughly reliable. The oscillating vacuum tube is, of course, the basis for any wireless telephone set using vacuum tubes. Thus with a simple circuit comprising an oscillating tube, it is possible to add the proper coupling and tuning arrangements, and then modify the antenna current by means of a simple telephone transmitter or microphone. However, in instances where heavy currents are handled for covering relatively long distances, it becomes necessary to employ special vacuum tubes known as modulators which modulate or modify the powerful currents which, if

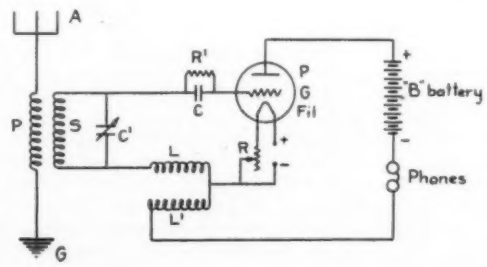


Fig. 8. Regenerative action through the use of electromagnetic coupling of grid to plate.

handled directly by the telephone microphone, would soon burn, cake or ruin the latter. However, the use of vacuum tubes for transmitting purposes is reserved for a later issue.

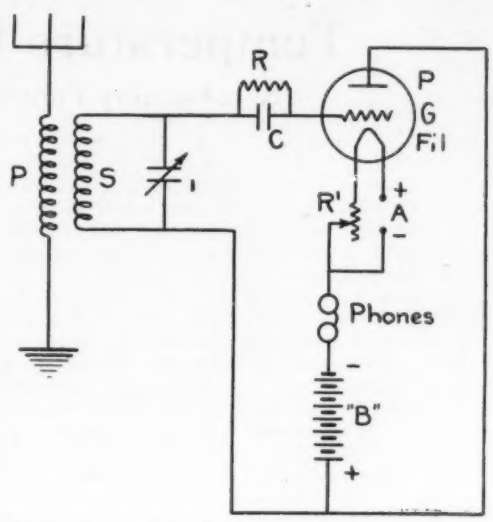


Fig. 9. A regenerative circuit using the capacity of the 'phones and "B" battery for electrostatic coupling of grid and plate.

Collapsible Floats for Aeroplanes

A writer in *L'Aérophile* describes a system of collapsible floats to insure the safety of airplanes when flying over the sea. The floats can be filled instantly with compressed air at the desired moment. The idea is due to Colonel Busteed, and has been developed both by him at Grain, and by Lieut. Bonnet-Labranche in France. The air floats have been fitted on some hundreds of British and French aeroplanes patrolling the North Sea, the Channel and the Mediterranean, and many aviators owe their lives to them. Aeroplanes fitted with these floats have been largely employed on aeroplane carrier ships in place of seaplanes, which are, of course, much less efficient.

Two or more floats of rubbered fabric are rolled up and stowed under the wings or under the fuselage, and these can be filled by means of a compressed air outfit in 30 secs. The number of bottles of compressed air required is reduced considerably by the addition of an injector with 3 concentric cones, inserted in the pipe leading from the compressed air bottle or bottles to the float bags. A jet of

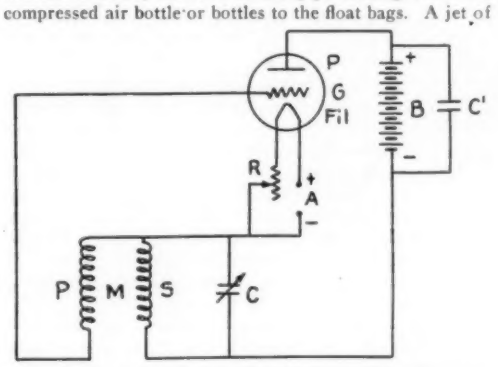


Fig. 10. Using the vacuum tube as a self-generator, for transmitting and other purposes.

the compressed air issues from a fine nozzle, whose walls are divergent towards the orifice, and by its expansion draws a large quantity of the external air through the triple opening between the three cones.

Several reservoirs of air in rubber bags are symmetrically arranged in the fuselage frame-work, and connected by tubing provided with taps by which the pilot can partially deflate them at altitudes. A hand-pump allows loss of air pressure due to leaks during long flights to be made up. The wheel of the chassis may in some cases be dropped off before alighting on the sea. A hydrovane is fitted in front of the chassis to prevent too great a shock to the inflated floats on alighting. A machine weighing 1,000 kg. requires floats of an aggregate volume of 2,000 litres. (*Technical Review.*)

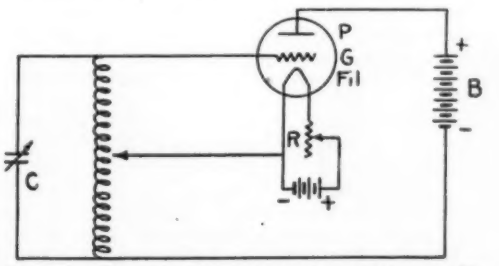


Fig. 11. The one-coil method of producing oscillations with vacuum tubes.

Temperature Uniformity in an Electric Furnace

A Laboratory Furnace that Gives a Uniform Temperature Throughout the Core

By John B. Ferguson

The problem of temperature uniformity in an electric furnace is intimately connected with almost all investigation carried on at high temperatures. For this reason it has generally been considered as a part of a large problem and has been solved to the extent demanded by the requirements of the work at hand. In the present paper the writer wishes to discuss the conditions essential for a proper control of the temperature distribution, and the previous attempts that have been made to attain these conditions; and to describe in detail a type of horizontal furnace which he has found suitable for investigations requiring a uniform temperature over the range from 620 to 1190 degrees.

The maintenance of a region of uniform temperature in an electric furnace requires that full compensation be made for the heat losses at all points within this region, and the ease with which such a compensation may be obtained is an inverse function of the magnitude of these heat losses. This is not, however, the only factor to be considered in determining the insulation required by any given furnace. If a uniform temperature is to be obtained this insulation must be thick enough to render negligible the effect of non-uniformity in the temperature of the furnace surroundings and if, further, a constant uniform temperature is to be obtained the insulation must be also of such thickness that fluctuation in his external temperature with time will be without effect. In the former case alternate thin layers of a good conductor and a good insulator may be used to advantage to replace thick layers of a slightly poorer insulator, giving the same uniformity of heat losses but with much reduced lag effects.

The heat losses are never uniformly distributed in a furnace, and the heat supply must likewise be non-uniformly distributed. If the heat losses are of different magnitudes but all similarly dependent on the furnace temperature (an unusual case) a non-uniform heater could be constructed which would afford a compensation over a range of temperatures; but if these losses are not similarly dependent on the furnace temperature (the usual case) then such a non-uniform heater would provide a compensation at one temperature only. In this latter case, if a compensation is desired over a range of temperatures, the single non-uniform heater must be replaced by as great a number of independent heaters as there are independent heat losses.

The ordinary electric furnace in which a column of air is heated is the best known example of a region with non-uniform heat losses and is the type the writer wishes particularly to consider. In such an air column, provided convection is eliminated, there will always be a short region having a fairly uniform temperature. The length of this uniform temperature region will be dependent upon the length of the furnace, and for some work a furnace sufficiently long to provide a suitable region of uniform temperature can be used without further attention to end conditions. But the usual problem confronting an investigator is to increase the length of this region without increasing the length of the furnace. The introduction of insulating plugs or baffle plates will cut down the end losses by conduction and radiation and will give a result similar to that obtained by lengthening the furnace. For this purpose a plug of good insulating material is much less efficient than a composite plug made up of good and poor conducting layers, the first of the former being on the inside of the plug next the region to be uniformly heated. Such a plug has two functions: (1) to reduce the end losses by insulating the region, (2) to distribute the heat losses and also the heat supply uniformity across the plug and thus take full advantage of the heating effect of the ends of the heater. This latter precaution is particularly important in furnaces of large diameter.

In many cases the region to be heated uniformly is such a large portion of the whole air column that even composite plugs are inadequate and in this case the simple uniform heater has to be discarded. A specially wound heater designed to give an increased heat supply at the furnace ends will increase the length of the region of uniform temperature and will yield a maximum length at one particular temperature, since with the materials at our disposal the average furnace must be so constructed that the relation of the heat losses to the furnace temperature varies. The use of a furnace of this type is naturally limited, since it is difficult to design a heater that will give the maximum length to the region of uniformity at a predetermined temperature. Special and separate end heaters independent of the main heater offer the most practicable solution, as they enable one to obtain equally good compensation over a range of temperatures.

In designing such a furnace the thickness of the layers of good and poor conducting materials employed will depend on the conditions under which the furnace is to be used and the degree of uniformity required. In general a horizontal furnace gives a better temperature distribution than a vertical furnace of the same dimensions. Two reasons may be given for this: (1) The convection currents in the air column of the vertical furnace are more active and may be considerable if the furnace is not gas tight; and (2) the temperature distribution over the outside of the vertical furnace is much less uniform than in the case of the horizontal furnace. The horizontal furnace has therefore been much more frequently used and was the type employed by the writer.

Almost all investigators in the field of high temperature have been obliged to consider the problem of temperature uniformity. In this paper it is obviously

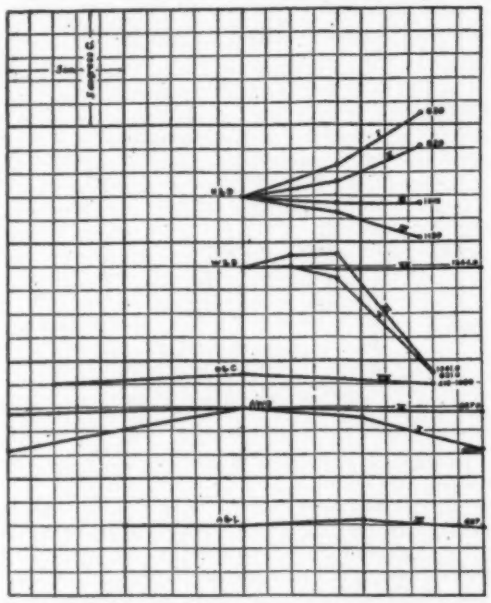


Fig. 1—Previous performances in temperature uniformity.

Curves I, II, III and IV: Uniformity attained in a furnace with crowded ends by Holborn and Day. Curves I and II indicate an over-compensation, and Curve IV indicates an under-compensation of the end heat losses. Curves V, VI and VII: Distribution obtained by Waidner and Burgess at different temperatures. Curve VIII: Results of a Day and Clement obtained by means of a furnace with three independent heaters over a range of temperature. Curves IX and X: Results obtained by A. W. Gray. IX shows the temperature distribution with composite plugs and end coils and X plugs alone. Curve XI: Results of Allen and Lombard.

impossible to present all the results that have been obtained and the writer has chosen to present only the work which best illustrates the points he desires to emphasize. In fairness to those quoted the reader should remember that most of them were interested in the development of a furnace suitable for their particular need and in that alone.

Among the earliest investigators to touch upon this problem were Holborn and Day,[1] who in 1899 experimented with both uniform and non-uniform heating coils. They found that the latter gave the better temperature distribution but with an optimum uniformity for a short range of temperature.

A somewhat more complicated furnace was used by Waidner and Burgess.[2] It consisted of two concentric furnaces, the outer having a long heater with crowded end windings while the inner was shorter and uniformly wound. In such a arrangement, the end and center heat supplies are only partially independent of each other and so the compensation is still a function of the temperature, although not as dependent on it as in the case of the single non-uniform coil. These conclusions are entirely borne out by their results.

In 1908 Day and Clement,[3] confronted with the same problem that had confronted Holborn and Day in 1899, were able with a new furnace to obtain along their gas-thermometer bulb a temperature distribution which did not vary over 1 degree up to 1200 degrees. This they did by means of independent auxiliary end heaters which, like the main heating coil, were wound (one in each end) on the inside of the furnace tube and were separated from the main coil by a layer of refractory magnesite cement.

Two slightly different types of furnace were used by Day and Sosman[4] in continuing the work of Day and Clement in 1910. Both had baffle plates in the unused portions of the air column which cut down the end losses by radiation. These end radiation losses, which seem to have been overlooked by all the previous investigators, were found to be of considerable magnitude. The furnaces differed only in the form of the heaters. In the first, the main heater was slightly crowded at the ends and inside wound, while the end coils were similar to those used by Day and Clement. In the second, the heating coil was divided into three units subject to independent control, and was wound on the outside of a thick tube of good conducting material. This second furnace yielded the better temperature distribution but could not be used at the highest temperatures.

The three-heater principle first used by Day and Cement was also employed by Gray,[5] who desired the greatest uniformity attainable. Instead of separating his good conducting baffles by air as Day and Sosmon had previously done, he used a layer of a good insulating material. This type of plug, though very similar in principle to the plug used by Day and Sosman, is probably better, since it is a better longitudinal insulator. The fact that metal baffle plates separated by thin layers of air form, in effect a composite plug conducting transversely and insulating longitudinally apparently did not occur to Gray, who independently later developed the idea. His first furnace, in addition to such plugs, contained thick-walled iron tubes and was heated by three independent heaters; the main heater was of basket weave; the other two were situated in the outer portion of the plugs. Evidence of severe local heatings led him to rebuild the furnace with two concentric heaters of basket weave and larger end coils which now were placed outside of the plugs and covered a considerable portion of the furnace ends.

Gray did not fully appreciate the value of the independent heater idea[6] and attributed his success mainly to other causes. His description implies that such plugs as are described above will enable one to use a furnace with crowded windings over a range of temperature. This is generally true, for if the windings are crowded so as only partially to compensate over the range of temperatures at which the investigator wishes to work the additional compensation may be obtained from the end heaters and a good temperature distribution will result. It will not be a convenient furnace to work with, however, as will be discussed later. But if the furnace is so wound that at any temperature within the range of temperatures considered a perfect compensation is made without the end coils, then at higher temperatures there will be under-compensation and at lower temperatures over-compensation by the crowded ends. Obviously, if there is over-compensation a plug by means of which the supply of heat at the ends can only be kept constant or increased offers no possibility of a solution. The basket weave would seem to have been a detriment rather than an aid, since a single main heater of that type was insufficient and two were necessary to avoid severe local heatings.

The form of the plugs is not as important as would appear from Gray's experiments. The main requisite is the separation of the heaters from the region to be heated by sufficient material to smooth out any local heating effects. Just how much latitude there may be in the designing of plugs, end coils, etc., may be gathered from the work of Allen and Lombard[7] and also that of the writer. The furnace of Allen and Lombard had flat end coils that did not cover the plugs, and also solid asbestos caps, while the main heater was a single coil wound on a helically grooved alundum tube with walls 0.5 mm. thick. With this furnace a uniformity equal to that obtained by Gray at approximately the

*Physical Review.

1 Holborn and Day, *Ann. d. Phys.*, LXVIII, 815, 1899; *Am. J. Sci.*, (4), 8, 165, 1899.
2 *Bull.* Bur. Standards, 3, 165, 1907.
3 Day and Clement, *Am. J. Sci.*, (4), XXVI, 405, 1908.
4 Day and Sosman, *Am. J. Sci.*, (4), XXIX, 93, 1910.
5 *Bull.* Bur. Standards, 10, 451, 1914.
6 In his discussion of this subject, Gray apparently overlooked the various investigations in connection with high-temperature thermometry, for he says: "Previous experimenters have tried to secure uniformity of temperature in an electrically heated air column by using the central portion of a long tube and by crowding the windings near the ends or other places where the heat was lost most rapidly," whereas several of the investigators referred to had already used independent end heaters.

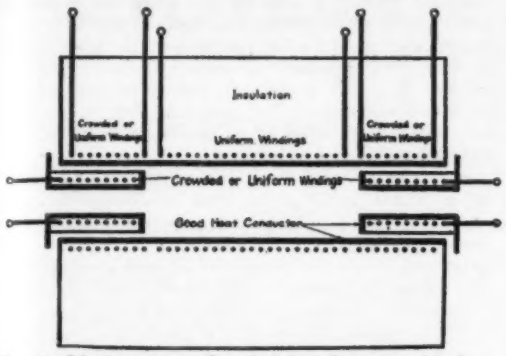


Fig. 2—Ideal section of cylindrical furnace with independent end heaters and plugs.

same temperature was obtained. In Fig. 1 curves representing some of the work referred to are given.

The actual design of any furnace is dependent on the purposes for which it is intended and the materials and facilities the experimenter has at hand. It is therefore doubtful whether any special design will have a very general application.

Nevertheless a description of a furnace may furnish the prospective designer with much useful information, and for this reason a description of a 45-cm. furnace capable of uniformly heating a region 6 cm. in diameter and 10 to 12 cm. long at temperatures ranging from 1000 to 1200 degrees, and maintaining this uniform temperature constant for long periods of time, will be given. In the development of this furnace a number of types were tested out, and of these a few proved satisfactory. The final changes were made with the intention of simplifying the construction and regulation rather than of improving the temperature uniformity, since the latter could not be obtained in several of the furnaces.

The final design is shown diagrammatically in Fig. 2. The end coils may be either crowded or uniformly wound, but the main central heater must be uniformly wound. Equally good compensation will result if the central heater has slightly crowded winding, but the resulting furnace is not as convenient to use over small ranges of temperature. For example, with a uniformly wound heater at a given temperature changes of ten degrees or so in the furnace temperature can be obtained by regulation of the central heater current without disturbing the compensation much, whereas in a central heater with crowded end windings, the same change in the current would have necessitated considerable adjustment of the end coil current. The end coils should be more closely wound than the center, thus increasing their resistance and lessening the danger of severe local heatings. The heaters are shown as independent units. This renders possible a variety of connections. In some of the writer's work the tube to be heated was very short and it was therefore desirable to heat the ends as little as possible. Satisfactory results were obtained by running the plug coils in series with the center coil and compensating by means of the end coils. In practically no experiments was a good compensation obtained by running the two end coils in series, as one end invariably required more current than the other.

The actual furnace is shown in Fig. 3. The large amount of insulation was necessary in order that a constant temperature might be maintained over long periods of time. The construction of the heater and plugs may be thus described:

Heater.—Two helically grooved alundum tubes were selected of such a size that the smaller readily slipped inside the large and was of 6 cm. inside diameter. A coil of 0.8-mm. platinum wire was wound on each end of the smaller tube for a distance of 10 cm. from the ends, and the whole was covered with alundum cement and baked. When hard the excess alundum was removed until this tube would just slide into the larger tube. A hole was bored through the large tube at each end at the inner edge of the end coils, and the inner wire ends, which had purposely been left long, were brought out through these holes. The smaller tube was then slid into the larger and these ends drawn tightly through and then wound back on the outer tube to its ends. The central portion of the outer tube was then separately wound with similar wire and the whole covered with alundum cement and baked. This peculiar method of winding was found to be necessary because alundum cement is not as good an electrical insulator as many suppose. Two furnaces, constructed with uniform main heaters extending the full length of the tube and with end heaters wound around the main heater and insulated from it by 0.5 cm. of alundum cement, did not

[7] *Am. J. Sci.*, 43, 175, 1917.

[8] A smooth (1-cm. thick) alundum tube upon which the end coils might have been more closely wound than the center would have been easier to handle, but unfortunately was not available.

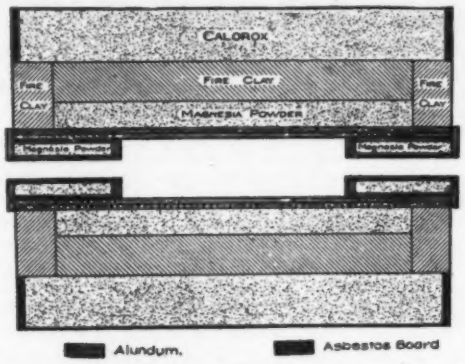
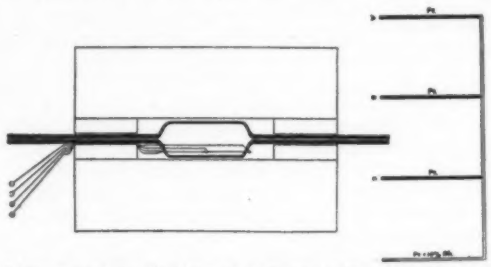


Fig. 3—Cross section of cylindrical furnace with end heaters and plugs showing details of construction.

even survive their trial heats, as the current arced from the main to the end coils, burning them out.

Plugs.—The principal details may be observed in Fig. 3. The inner and outer alundum tubes were cemented to an alundum disc with water glass. The space between the tube was filled with freshly ignited magnesia powder to within 1 cm. of the end and this magnesia held in place by means of a paper washer. The remainder of the space was filled with alundum cement and the whole baked. In order to insure a good tight fit the outer alundum tube was usually coated with alundum cement,



Figs. 5 and 6—Section of furnace with gas bulb and compound thermo-element, and detail of the latter.

and when this had hardened the plug was filed down until it would just slide into the furnace. The inside of the outer edge of each alundum disc was covered with asbestos wool stuck on with water glass, thus insuring a tight fit when the plug was pushed home and eliminating any radiation losses through the crevices.

The use of alundum with burnt magnesia and fireclay in all the hot portions of the furnace assures consistent results from the furnace day after day even at quite high temperatures with practically the same current. The calorox which forms the outer insulating

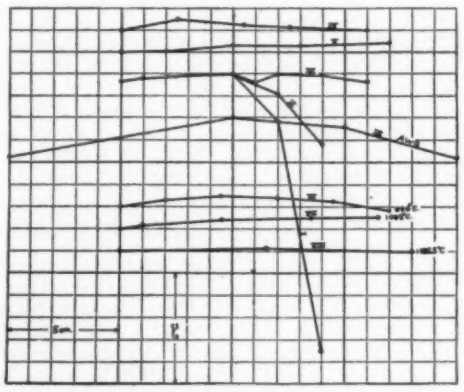


Fig. 7—Temperature uniformity attained.

Curve I: Furnace with end plugs and uniformly wound heater. Curve II: Furnace with end plugs and crowded end windings on heater. Curve III: Furnace with flat end heaters similar to those used by Allen and Lombard, with slightly crowded windings on ends of main heater and with plugs. Curve IV: Furnace similar to III with the exception that the furnace heater was uniformly wound and the plugs contained extra end heaters. Curve V: Furnace is described in detail in the text. (Curves I-V at approx. 1000 deg.) Curve VI: Furnace V at 620 deg. Curve VII: Furnace V at 1002 deg. Curve VIII: Furnace V at 1186.5 deg. Curve IX: Curve VII of Fig. 1 repeated. When compared with Curves I and II, in which likewise only unheated end plugs were used, an idea may be gathered from the adverse conditions under which the writer worked as compared with those of Gray.

layer is unsuitable at temperatures as high as 1000 degrees. The outer shell is of sheet iron, painted with aluminium paint. We find that this paint reduces the total heat losses by reducing the radiation, thereby increasing the temperature of the shell and decreasing the temperature gradient across the insulation.

Electrical Connections.—As has already been stated, the exact method of making electrical connections will depend on the particular use that is to be made of the furnace. Three separate electrical controls will be almost always essential, although the current required by

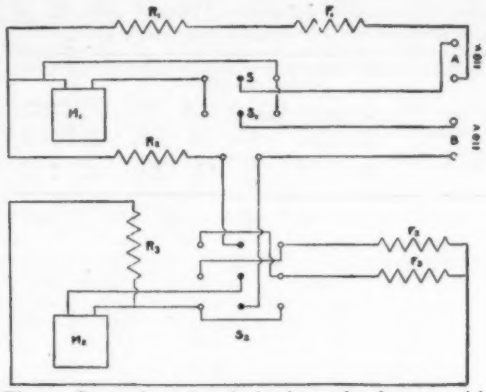


Fig. 4—Convenient electrical scheme for furnace with independent end coils.

the end heaters will usually be very nearly of the same magnitude. The writer was able to take advantage of this fact in developing a set-up whereby all the adjustments could be obtained from two main circuits with considerable saving both of current and the operator's time.

A diagram of these connections is shown in Fig. 4. *A* and *B* are in the two main circuits. In *A* the current always flows through the furnace coil F_1 and the variable resistance R_1 and can be made to pass through the ammeter M_1 by means of the switch S. In *B* the current has two routes, depending on the way the switch S_2 is thrown. As in *A*, the current always passes through a variable resistance R_2 and at will may be made to pass through M_1 by means of switch S_1. The function of the three-way switch S_2 is to place the variable high resistance R_3 in parallel and the ammeter M_2 in series with one of the furnace coils, either F_2 or F_3, at will. If the switch S_1 is thrown to the left and the switch S_2 to the right the current follows he route S_1, M_1, R_2, F_2, R_2, in parallel with F_3 and M_2, and back. The upper ammeter shows the total current, *i. e.*, current through F_2 and the lower the current through F_3. With this arrangement the current through F_3 will always be equal to or less than the current through F_2 but by reversing the switch S_2 the position of these furnace resistances is reversed and so all the required adjustments can be made. If nearly the same amount is required through F_2 and F_3 the amount wasted in R_3 will be very small.

Temperature Measurements.—In the earlier work a single platinum-platinrhodium thermoelement tube was used. It was mounted in a Marquardt porcelain thermoelement tube having two small holes bored in the closed end, through which the wires passed; the junction was bare and bent so that it would come in contact with the gas balloon which was to be maintained at constant uniform temperature. The thermoelement tube could be inserted or withdrawn from the furnace and the measurements were always made when the tube was about to be withdrawn, since on inserting the tube the uniformity was somewhat disturbed. When the local heatings were found negligible this thermoelement was replaced by a compound element of the form shown in Fig. 6 by means of which direct or differential temperature measurements could be obtained at any one of three points with but four leads. Fig. 5 shows one of these later set-ups. At 1000 deg. no trouble with leakage was experienced, but at 1200 deg. it caused considerable trouble, especially whenever any part of the element came in contact with the hot alundum furnace tube, and necessitated careful shielding in the furnace itself. This was obtained by placing in the furnace a sleeve of thin platinum foil connected to the outer shield, and carefully insulating the same from the element itself by enclosing most of the latter in Marquardt porcelain. The measurements were made by means of the usual potentiometer set-up.[9]

In most of the investigations no greater uniformity than —0.5 degree was necessary and no attempt was made to improve on this. The apparatus is undoubtedly capable of producing a uniformity of —0.2 degree, the limit set by local heatings, provided the experimenter is willing to take the trouble with the current adjustments.

Figs. 7, 8 and 9 are curves representing the results. Unfortunately furnace V was not used with the same set-up on different days, so that no comparison can be made of its performance on different days with the same current. At 1190 degrees with a porcelain tube 3 cm in diameter at the center and somewhat smaller ends the current required on 110-volt circuit to give a uniformity of —0.5 degree was: Left, 5.65; center, 5.50; right, 5.55 amp. Furnace IV was constructed of exactly the same material as furnace V although of different shape, and one may with reasonable certainty infer that if furnace IV would reproduce a given temperature uni-

formity furnace V would also. Table I gives the results obtained in four separate runs with furnace IV.

TABLE I.—ENERGY REQUIRED UNDER DIFFERENT CONDITIONS OF END RADIATION

Set Up	Date	Left Coil, Amp.	Center Coil	Right Coil	Temperature Distribution
Porcelain tube *A*..	Dec. 7, 1915	3.35	5.1	3.30	1001.0 ± 0.5°
	Jan. 6, 1916	3.35	5.1	3.35	1000.4 ± 0.5°
Transparent silica tube *B*	Feb. 21, 1916	4.04	4.93	4.06	1000.0 ± 1.0°
	Mch. 15, 1916	4.05	5.02	4.06	999.5 ± 1.0°

Particular attention is directed to the great difference in the current required by the end coils in the two different set-ups. The heat lost by radiation through a transparent silica glass capillary tube of 1-cm. outer diameter and 1-mm. bore necessitated the increasing of the current in the end coils from 3.35 to 4.06, an actual increase of 0.71 amp., or 21 per cent, and confirmed the observation of Day and Sosman on the magnitude of the end radiation heat losses.

The production of temperature uniformity in an electrically heated air column can best be accomplished by means of three independent heaters in addition to end

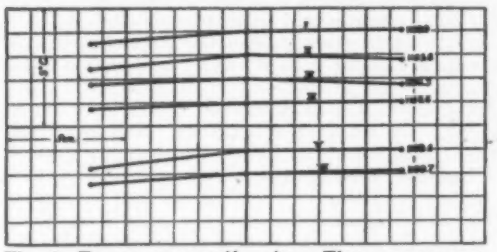


Fig. 8—Temperature uniformity. These curves represent the furnace distribution obtained during a series of experiments at approximately 1190 degrees

plugs. The entire region to be heated should be surrounded by a layer of conducting material sufficient to smooth out any local heatings, and the whole furnace should be so insulated that the effect of non-uniformity in the temperature of the furnace surroundings is rendered negligible. The use of alternate layers of good and poor conductors will reduce the total amount of insulation necessary, but if constancy of temperature as well as uniformity is desired the insulation must be

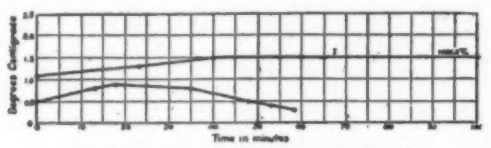


Fig. 9—Temperature constancy.

Curve I: The fluctuations in the furnace temperature with time in part of a four and a half run with furnace IV at 1001.4 deg. Curve II: The fluctuations in the furnace temperature with time in a run with furnace V at approximately 1190 deg.

of such thickness as to eliminate the effect of temperature fluctuations in the furnace surroundings during the period the furnace is in use. This type of furnace has the advantage that it may be converted into a simple type if less uniformity is adequate by merely changing the mode of connecting the heaters.

A furnace embodying these principles is described in detail. This furnace yielded a temperature uniformity of —0.5 degrees at temperatures ranging from 620 to 1190 degrees, and at 1000 and 1190 degrees a temperature constancy of —0.25 degrees for periods of time exceeding an hour. With greater care in adjustment a uniformity of 0.2 degree should be possible, and without doubt the furnace could be run at much higher temperatures without great loss in efficiency. The furnace is economical of current and will reproduce practically the same condition on different days with the same amount of current provided the temperatures are below that at which magnesia powder begins to pack.

Some results indicative of the behavior of several different furnaces and set-ups are presented for their comparative value and also with the view of indicating the magnitude of some of the effects obtained.

Geophysical Laboratory, Carnegie Institution of Washington, Washington, D. C.

Transportation in the Philippines

(*Continued from page* 339)

reached. While the climate is mild, construction work involved taking care of workmen and superintendents over nights. To meet this requirement, a number of camps were constructed of a primitive and temporary character. As to scenery—one always finds in mountainous countries an abundance of it. It is the one thing that is certain. Waterfalls, wooded heights, precipitous mountain flanks, dashing streams—everything of this kind, one is pretty sure to find. In such tropical and mountainous regions as the Philippines there is also the luxuriance of vegetation.

Luzon is the northernmost and Mindanao the southernmost of the great islands. The principal islands lying between these two are each traversed longitudinally by a single mountain range. The northern part of Luzon and the whole of Mindanao are covered with mountain ranges. In general, the ranges in the Philippines run north and south or deviate from this up to half a right angle. In fact, the archipelago is thought to be probably the unsubmerged portion of a mountain system belonging to the continental system of Cochin China in southeast Asia. The mountains left above the sea rise, some of them, to goodly heights. Along the eastern coast of northern Luzon is the Sierra Madre Range where the peaks rise to 4,500 feet or more and are generally as high as 3,500. Accordingly, in the matter of height this range is comparable with the Catskill Mountains in New York. On the western side of this part of the big island, are mountain ranges extending, one of them, as far south as Manila Bay. Mt. Data in the north rises to a height of 7,364 feet and a number of peaks further south have heights in the neighborhood of 5,000 feet. Between the mountains on the east and west of north Luzon is a very considerable valley drained by the largest stream in the Philippines. This is the Cagayán River, which is some 200 miles in length. A little to the south of the sources of this north-flowing stream, are the head waters of Agno River. This river runs south and then swings in a great semi-circle to empty its waters in Lingayan Gulf. Baguio, the resort already mentioned, lies on the heights above and to the west of the upper reaches of the Agno; and the district around Naguilian—a name previously mentioned—lies further west. Baguio is high up on the eastern flank of the mountain range here, and Naguilian is on the western side. Naturally, the Benguet and Naguilian roads both must cross the Agno. Manila is some 125 miles to the south of these points in and near the mountains.

Some reference has already been made to the Manila North Road. The last link for this important road was located, after much difficulty, some years ago. The experiences gained in locating in this connection may be regarded as somewhat typical of Philippine roadmaking. The last link was to be located in the region near the border between the provinces of La Union and Pangasinán. This is inland to the east of Lingayan Gulf. Early in 1915 a surveying party set out from Aringay, a station on the railway which skirts the west shore of the Gulf, to explore the valley extending south. The idea was to connect with a trail and utilize it more or less. But this trail was ascertained to lie "too far to the south, crossed too many creeks, was low level, and had several long steep grades, improper in a first-class road." A second foot-trail in the neighborhood was then investigated, but found unsuitable—partly, because the railroad running to Baguio was occupying nearly all the available space on the north bank of the Aringay River. Finally, a third route was explored. This lies between the others. The engineer in charge, Mr. M. Kasilag, states that no difficulty was encountered for the first seven kilometers, but that when the main divide, between Rosario and the coast, was reached, "a perplexing problem was met. The west side of the divide was butressed by a series of sharp adobe hills separated by deep gullies, each little hill connected to the main ridge by a narrow saddle, as if these hills had once formed integral parts of the big mountains. The first location was tried by cutting across the saddles, looping around a few of the hills, and zigzagging down to a crooked stream below." When the grade was determined it was found to be 6 and 7 per cent for a stretch of some 1,100 meters (2-3 of a mile). This was thought unsuitable. "To reduce the grade to 5 per cent a greater distance would be required, and this was secured by going over three saddles on a line and then rounding a hill that was hardly 30 meters across at the base. In the return crossing of the ravines, the location hugged the sides of all the hills in the series, producing a continuous succession of small reverse curves, and involving a fill of nearly 12 meters in one of the deepest ravines. The limiting gradient of 5 per cent was secured, however, clear down to the stream below, with an easement level half way between the top and bottom of the grade." Speaking of curves, I may be permitted to digress a moment and call attention to the beautiful little horse-shoe curve at kilometer 26, on the Loay interior road, Bohol. In April of this year it was a wonderful white loop in the midst of the dark foliage of the surrounding country. But, to get back to the location work on the Manila North Road. On the other side of the crooked stream, a 10 per cent grade developed when the route had crossed over another saddle and encountered there the junction of four different divides, which met one another in a kind of star formation. The survey work was difficult and expensive because of trees and vines and the like. One trial resulted in a 10 per cent grade for 70 meters at the end of a line. It was impossible to see the ground beyond the turn of the hill, and the location "was thought to be the best that could be made." Upon its rejection "it was only after a thorough cutting and clearing of the whole mountainside had been done that the problem was solved in the shape of a horseshoe over three wide and deep gullies beyond."

It will be gathered from these glimpses of the work going on that the job of supplying the whole archipelago and its 8,000,000 population with a thoroughly usable system of roadways is a big enterprise. It will last for years and involve the expenditure of millions of dollars. But during this period and afterwards, there should be a wonderful development of the great resources of this distant possession of the United States.

9 W. P. White, "Potentiometer Insulation, Especially for High Temperatures and Thermoelectric Work," *Physical Review*, XXV, 334-352, 1907.

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